The Engineer

LONDON, FRIDAY, JUNE 20, 1941.

PUBLIC NOTICES

WOKINGHAM RURAL DISTRICT COUNCIL

WOKINGHAM WATER SUPPLY, CONTRACT No. 5, PUMPING PLANT

Tenders are Invited for the PROVISION and INSTALLATION of ELECTRICALLY OPERATED PUMPING PLANT in DUPLICATE, capable of delivering 40,000 gallons per hour, from two 18in. diameter bore-holes, in a 6ft. diameter well, 24ft. deep, and all WORKS incidental thereto.

Plan, specification, and general conditions may be seen at the office of the Engineers, Messrs. A. P. I. Cotterell and Son, 54, Victoria Street, Westminster, S.W.1, during the hours of 9.30 a.m. to 11.30 a.m. and 3 p.m. to 5 p.m., or at the office of the undersigned, by intending contractors, on or after 25th June, 1941. Copies of the specification and form of Tender may be obtained from the Engineers by intending contractors on payment of the sum of Three Guineas, which will be returned on receipt of a bona-fide Tender (not subsequently withdrawn) and all other documents supplied.

Tenders, on the forms provided, enclosed in sealed envelopes, must be delivered to the undersigned, endorsed "Wokingham R.D.C. Water Supply, Contract No. 5," not later than Twelve Noon on 15th July, 1941.

Contractors will be required to provide securities for performance of the contract.

The Council do not undertake to accept the lowest or any Tender.

GEOFFREY HEATH,
Clerk.

Council Offices,
Shute End,
Wokingham, Berkshire,
20th June, 1941. 7538

NORTHAMPTON POLYTECHNIC

ST. JOHN STREET, LONDON, E.C.1

Lecturer Required for the Civil and Mechanical Engineering Department. Candidates should have a University Degree and should be qualified in General Mechanical Engineering subjects. Qualifications also in either Heat Engines or Aeronautics desirable, though not essential.

Salary in accordance with London Burnham Scale.

Particulars and form of application may be obtained from the Secretary. Applications should be submitted by 7th July.

S. C. LAWS, M.A., M.Sc.,
7539 Principal.

PATENTS AND DESIGNS ACTS, 1907 TO 1939

DAVIDSON MANUFACTURING CORPORATION

Notice is Hereby Given that DAVIDSON MANUFACTURING CORPORATION, a corporation organised under the laws of the State of Illinois, United States of America, of 1020, West Adams Street (formerly 737, West Jackson Boulevard), City of Chicago, State of Illinois, United States of America, SEEK LEAVE to AMEND the SPECIFICATION of LETTERS PATENT No. 530,970 granted to them for an invention entitled "Improvements in Folding Machines."

Particulars of the proposed amendment were set forth in No. 2734 of the Official Journal (Patents), published on 18th June, 1941.

Any person or persons may give Notice of Opposition to the amendment by leaving Patents Form No. 19 at the Patent Office, 25, Southampton Buildings, London, W.C.2, within one calendar month from the date of publication of the said Journal.

M. F. LINDLEY,
7541 Comptroller-General.

SITUATIONS OPEN

COPIES OF TESTIMONIALS, NOT ORIGINALS, UNLESS SPECIFICALLY REQUESTED.

TO ADVERTISERS UNDER BOX NUMBERS IN SITUATIONS OPEN SECTION.

For the benefit of applicants, the Proprietors are prepared to insert brief notices that vacancies are filled, upon receipt of notifications from the Advertisers. These notices (limited to one line) will be free of charge, and co-operation is asked for.

IMPORTANT

Advertisers in Situations Open Column should make themselves acquainted with the terms of

STATUTORY RULES & ORDERS 1940 No. 877

RESTRICTION ON ENGAGEMENT ORDER

WANTED IMMEDIATELY, BOILER-HOUSE CHARGE HAND; must be accustomed to Control, Care, and Maintenance of Lancashire Boilers, Auxiliary Plant; capable of Taking Full Charge. London area, permanent, good salary.—Address, 7542, The Engineer Office. 7542 A

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ASSISTANT BUYER REQUIRED by Large Engineering Firm engaged on work of national importance. Men who have had experience of Buying, with special reference to the Auto. Industry, and who have first-class knowledge of Modern Purchasing Routine, should apply in writing, giving age, details of experience, and salary required.—Address, 7535, The Engineer Office. 7535 A

The Engineer

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REPRESENTATIVE REQUIRED for the Midlands to Handle New Excavators and Cranes. Particulars of experience, salary expected, and age.—Address, 7527, The Engineer Office. 7527 A

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The Engineer

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"THE METALLURGIST"

This Supplement, which deals with the Science and Practice of Metallurgy, both ferrous and non-ferrous, is published free with the last issue of THE ENGINEER each alternate month. Next due, August 29th.

ADVERTISEMENTS

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Letters relating to the Advertisement and the Publishing Department of the Paper are to be addressed to the Publisher, all other letters are to be addressed to the Editor of THE ENGINEER.

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The fact that our Enquiry Department is unquestionably filling a want in the engineering world daily becomes more apparent, and the Proprietors of "The Engineer," welcome enquiries from all who require technical or commercial information.
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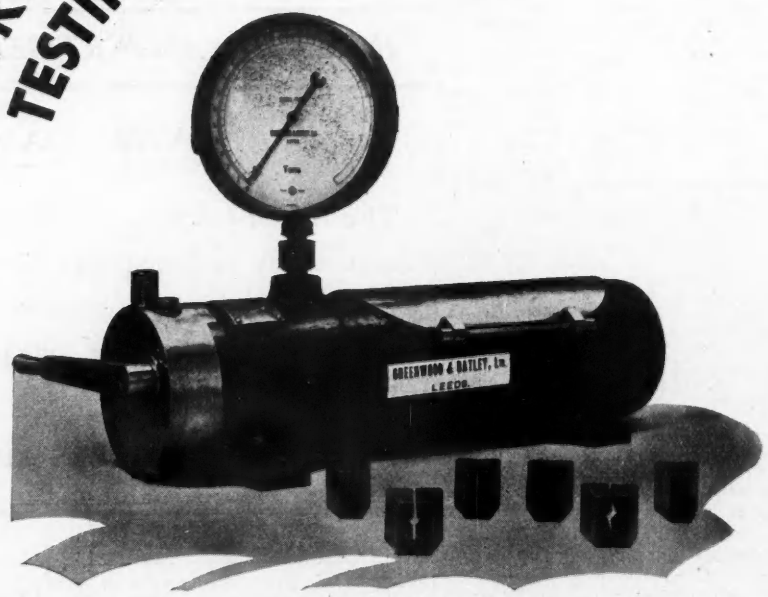

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T 2a

A Seven-Day Journal

Birthday Honours

In the official list of birthday honours bestowed by the King, the following names appear :—Knighthoods are conferred upon Colonel Arthur Stanley Angwin, Engineer-in-Chief of the General Post Office ; Mr. Frederick George Binney, export manager of the United Steel Company, Ltd.; Mr. James Callander, director and general manager of the Vickers-Armstrongs' Barrow-in-Furness Works and Walker-on-Tyne Shipyard ; Mr. Patrick Hennessy, member of the Advisory Council to the Minister of Aircraft Production, general manager of the Ford Motor Company, Ltd.; Mr. Arthur Matthews, Chairman of the Alloy and Special Steels Committee, Ministry of Aircraft Production ; Mr. Frederick Ernest Rebbeck, chairman and managing director of Harland and Wolff, Ltd.; and Mr. John Douglas Ritchie, general manager of the Port of London Authority. In the Dominions Services List a knighthood is conferred upon Professor J. P. V. Madsen, Professor of Electrical Engineering in the University of Sydney and Chairman of the Radio Research Board, Australia. Mr. Frank Gill receives the K.C.M.G. for his services in the development of the telephone industry and international telephony. The C.B.E. is conferred upon Mr. R. Alsop, general manager of the Consett Iron Company, Ltd.; Professor F. C. Bartlett, member of the Flying Personnel Research Committee ; Major G. P. Bulman, Director of Engine Development and Production, the Ministry of Aircraft Production ; Mr. Percy Good, Deputy Director of the British Standards Institution ; Mr. A. J. Hendin, special director of Vickers-Armstrongs, Ltd., and resident manager of the Walker-on-Tyne Shipyard ; Mr. J. Leek, general manager and director of B.S.A. Guns, Ltd.; Mr. J. C. Little, late President of the Amalgamated Engineering Union ; Mr. A. J. Lyddon, Deputy Chief Engineer, the Ministry of War Transport ; Mr. F. S. Mitman, Controller, Sheet and Strip, Light Alloy and Magnesium Control ; Mr. R. C. Thompson, managing director of Joseph L. Thompson and Sons, Ltd., Shipbuilding Yard, Sunderland ; Mr. M. T. Tudsbery, civil engineer of the British Broadcasting Corporation ; and Mr. A. Williamson, managing director of William Beardmore and Co., Ltd., also Chairman of the Ministry of Supply Gun Forging Committee. The honour of C.B. is conferred upon Mr. F. A. Whitaker, Civil Engineer-in-Chief, the Admiralty. Other awards include the Kaiser-I-Hind Gold Medal for Service in India to Mr. R. H. T. Mackenzie, Chief Engineer, P.W.D. Buildings and Roads, Bikanir State, Rajputana ; and the K.C.I.E. upon Sir Alexander Roger, chairman of British Insulated Cables, Ltd., Chairman of the Tank Board and Leader of the recent Ministry of Supply Mission to India.

Accidents on British Railways in 1940

The annual report of Sir Alan Mount, the Chief Inspecting Officer of Railways, issued last week, shows that in train and movement accidents in Great Britain last year there were 453 fatalities, as against 358 in the previous year. Train accidents were remarkably few, but included one which resulted in twenty-seven fatalities. The deaths from train accidents were forty passengers and eight railway servants, as compared with annual averages for the previous five years of seventeen and ten respectively. Among passengers the liability to casualty in train accidents was one killed in some 32·5 millions carried and one seriously injured in 28·3 millions. In accidents connected with the movement of railway vehicles exclusive of train accidents, 100 passengers were killed, as compared with an average of sixty-nine for the previous five years. The majority of these fatalities resulted from attempting to enter or alight from trains (twenty-eight), falling from trains (thirty-one), and falling off platforms (twelve). It is stated that these accidents were mainly due to misadventure or were caused by want of caution on the part of passengers themselves. Of the 100 fatalities, fifty-nine occurred after dark, and restricted lighting was stated to be a contributory factor in twenty-five cases. Apart from train accidents, railway servants suffered 281 fatalities, against 249 in 1939 and an average of 228 for the five-year period 1935–39. The black-out, it is stated, caused delay and congestion, and undoubtedly contributed to the incidence of accidents. The year opened with a prolonged period of severe weather and much sickness, and the former directly accounted for twelve fatalities. The report refers to the high standard of safety maintained, notwithstanding the difficult operating conditions under which depleted staffs were called upon to handle increased traffic, much of it in altered flow. The evacuation from France and the air raids of late summer and autumn added considerable strain, which resulted in some loss of efficiency and an increase in casualties not directly caused by enemy action. But the way in which all departments met the situation was beyond praise and justifies confidence for the future that services will be maintained and repairs of bomb damage will continue to be effected with equal promptitude. Everything possible is being done to assist in improving operating efficiency and safety within the limits prescribed by war conditions. As a measure of wartime economy the report has not been printed and put on sale in the usual way. Copies of it, however, have been circulated to the railway companies and to the trade unions concerned, and will also be available for inspection at the Ministry of War Transport library.

Committee on Cement Production

It may be recalled that on January 4th Lord Reith appointed a Committee under the chairmanship of Mr. George Balfour to consider and report to the Minister of Works and Buildings, bearing in mind the probable demands for cement in meeting current needs and in post-war construction, and taking into consideration economic, strategic and other factors affecting the allocation of cement, whether new cement works should be established, existing ones extended, or old plant modernised, and, if so, what general considerations, financial, geographical and economic, should apply. The report of the Committee has now been published by the Stationery Office, and the summary of the conclusions reached is as follows :—(i) The existing works are capable of producing all the cement that is likely to be needed in wartime. (ii) The existing works, together with the projected extensions, should together be able to meet the greatest demand that might arise during the first two years after the war. (iii) At any time during the first two years after the war a conclusion can be arrived at as to whether it is necessary still further to increase production by the establishment of new works. (iv) The position should be reviewed by the Ministry of Works and Buildings from time to time, say every six months, and the necessary steps taken if in the interval some new factor comes to light which would modify the facts as they have been presented to the Committee at the present time, and make it necessary to undertake extensions during or after the war period. (v) The Ministry of Works and Buildings, the report states, should keep in contact with the industry to encourage and assist the preparation of plans for extensions, so that when it is necessary to extend no time will be lost in considering the preliminary stages. The Ministry should also take steps to ensure that no undue pressure is exercised by the established manufacturers to prevent the setting up of new works which are in themselves economic propositions.

Sir Charles Craven's New Appointment

At the request of the Prime Minister, Mr. Winston Churchill, and the Minister of Aircraft Production, Lieut.-Colonel Moore-Brabazon, the board of Vickers, Ltd., has agreed to release Sir Charles Craven to take up the newly created appointment of Controller at the Ministry of Aircraft Production. Sir Charles, it is announced, will be responsible to the Minister of Aircraft Production for all matters connected with production. Sir Charles took up his new appointment this week. He joined the Air Council in May of last year, and became the Chairman of the Air Supply Board, which replaced the Air Council Committee of Supply. When Sir Samuel Hoare was Air Minister, Sir Charles was put in charge of aircraft production. At that time he was released from his duties with Vickers, and continued in office in the Ministry until November last, when he resigned from the Air Council and resumed his duties as chairman and managing director of Vickers-Armstrongs, Ltd., director of Vickers, Ltd., and the chairman of a number of other allied companies.

Essential Work Order for the Building and Civil Engineering Industries

The Essential Work (Building and Civil Engineering) Order, 1941, which was signed on Monday, June 9th, should be of great value in securing the necessary labour to speed up the building of vital aerodromes, factories, and other constructional works of war importance. The main provisions of the Order are that when an undertaking is scheduled the right of the employer to discharge a worker and of the worker to leave is strictly controlled, and is, in general, subject to the permission of a National Service Officer and to at least one week's notice ; a guarantee of a certain minimum time-rate of wages is given, subject to conditions laid down in the Order ; and cases of alleged absenteeism, unpunctuality, failure to comply with lawful orders and behaviour impeding production are dealt with under a special procedure. One of the innovations is that not only a particular undertaking, but a building "site" (and all or any of the undertakings engaged on it) can be scheduled under the Order. Another is that scheduling can be limited, if necessary, to specified classes and descriptions of persons employed by the undertakings scheduled. As with other Orders, it is an essential of scheduling that there shall be satisfactory conditions of employment and welfare in the undertakings or on the sites scheduled. In all cases where it is practicable and desirable, provision for a system of payment by results should be made, but the wording of the Order allows full elasticity as to the method of applying the principle, and would cover a wide range of variations, including a system of bonus on output. Scheduling in the building and civil engineering industries will begin with a few large contracts of special importance. It is hoped that it can be extended quickly to other parts of the Government building programme. Another provision of the Order is for the enrolment of building volunteers, who, in return for special privileges, will be ready at once to go to work wherever in Britain they are most needed. It is hoped to raise a large body of picked workers for this purpose. The Order is a part of a wider scheme framed by the Minister of Works and Buildings for the control and direction of the two industries in the interests of the war effort.

Employment Returns

It was officially announced by the Ministry of Labour and National Service on Wednesday, June 18th, that the number of men and boys registered at employment exchanges in Great Britain as wholly unemployed at May 12th was 141,984, a decrease of 15,255 as compared with April 21st. Of this total, 36,393 had been classified by interviewing panels as unsuitable for ordinary industrial employment. Those registered as on short time or otherwise temporarily suspended from work on the understanding that they were shortly to return to their former employment numbered 27,784. This was a decrease of 14,011 as compared with April 21st. Those registered as unemployed casual workers (being persons who normally seek their livelihood by jobs of short duration) numbered 12,055, a decrease of 3460 as compared with April 21st. The corresponding figures for women and girls at May 12th were 148,328 wholly unemployed (of whom 4021 had been classified by interviewing panels as unsuitable for normal full-time employment), 37,960 temporarily stopped, and 877 unemployed casual workers. As compared with April 21st, the numbers wholly unemployed showed a decrease of 13,205, those temporarily stopped an increase of 4382, and unemployed casual workers an increase of 26. A table showing the difference between April 21st, 1941, and May 12th, 1941, in the total numbers unemployed on the registers in the various administrative divisions indicates that there has been a reduction of unemployment in all divisions with the exception of the North-Western Division, in which the numbers of unemployed persons increased by 1203.

Radio Location

Replying to a question in the House of Commons regarding the recent speech, recorded in our Journal note of May 23rd, by the Canadian Minister of Defence on a device for the location of enemy aircraft, Mr. Atlee, the Lord Privy Seal, said that, thanks to the brilliant work of our scientists, great progress had been made in devising means of helping the Fighting Forces in their task of locating and destroying enemy aircraft. Our industries, he continued, were now turning out increasing quantities of ingenious apparatus which for its maintenance and repair demanded large numbers of skilled men, especially radio mechanics. Training in this work was being given by the universities and technical colleges throughout the country, and help was being given by the Dominions and other parts of the Empire. Canada especially, said Mr. Atlee, was organising powerful aid. In a broadcast address to America delivered early on Wednesday morning, Lord Beaverbrook appealed for at least 10,000 workers to assist in the development and maintenance of radio location apparatus. The work of development has, it is now revealed, steadily advanced since the first experiments near Daventry in March, 1935. The original idea was that of Mr. R. A. Watson Watt, Scientific Adviser on Telecommunications to the Air Staff, and as the result of the work of young scientists and Royal Air Force officers, it was well advanced when the threat of hostilities came in 1938. Since that time it has been the task of scientists, engineers, and manufacturing firms to produce in combination the best possible equipment for the detection and location of enemy aircraft. It may now be stated that, broadly speaking, radio location is a system of sending out far beyond our shores ether waves which are unaffected by cloud, fog, or darkness. Any solid substance, such as an aircraft, which is in the path of these waves sends back a reflection to the detecting station and thus reveals its approach. These ether waves are being sent out at every minute of the day and night. They obviate the necessity of maintaining standing patrols of fighter aircraft, releasing men and machines for the actual business of tackling raiders as soon as their presence has been discovered.

The Mechanical Properties of Solids*

By Professor E. N. DA C. ANDRADE, Ph.D., D.Sc., F.R.S.

No. II

(*Continued from page 383, June 13th*)

STRENGTH OF METAL SINGLE CRYSTALS

WHEN we turn to the question of strength we enter a very difficult field. The simplest case is that of brittle fracture. The determining factor here is the tension normal to the plane of rupture. If the critical tension N which leads to fracture; the critical shear stress S; and the crystal structure are such that a crystal can be so disposed that the stress resolved normal to the plane of rupture is N, while the stress resolved along the glide direction is less than S, fracture without glide can take place. With crystals of hexagonal structure it is possible to realise these conditions, and we find the recorded critical tensions run from 120 to 18 bars with different metals and different temperatures; for instance, 20 bars for the basal plane of zinc at —185 deg. Cent. This compares with 1·3 kilobar for polycrystalline zinc and a theoretical value of some 100 kilobars.

Brittle fracture is, however, rather the exception than the rule. For metals of cubic structure, where there are many alternative equivalent glide planes,

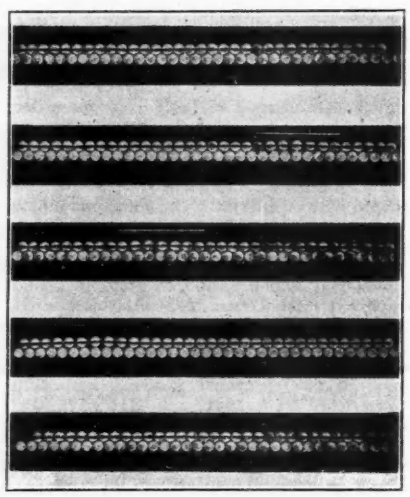


FIG. 16—MODEL ILLUSTRATING GLIDE

the values of N and S and the geometry of the crystal apparently prohibit it. Even with hexagonal metals glide is the normal occurrence.

The inception of glide, which takes place by sudden avalanche-like slipping in the neighbourhood of isolated planes, occurs at very low stresses, of the order of 20 bars, much less than one-thousandth of the theoretical strength. If we wish to consider rupture, we are confronted with a variety of processes that can take place before actual fracture. We have in general a progressive hardening as movement proceeds, but quite often, especially with hexagonal metals, we ultimately get twinning, leading to glide on a fresh set of planes at a new inclination, which is followed by fracture. In the case of hexagonal metals, where brittle fracture can be brought about by suitable geometrical conditions, the glide which takes place before rupture can either raise or lower the breaking strength, according to temperature. For these metals the breaking strength is, however, of the same order as that in the case of brittle fracture. In the case of certain metals which will be mentioned later, glide can lead to very great hardening, so that stresses of nearly a hundred times the critical shear stress can be supported, but here, as will be pointed out, the result of glide is that the specimen has lost much of its monocrystalline character. It remains true that a single crystal is very soft.

Before we look at any further facts, it may be well to consider the attempts that have been made to explain theoretically the outstanding difficulties offered by the softness of the crystals—their proneness to glide under very small shear stresses. The atoms are bound in their places by interatomic forces, the potential of the field of force having a minimum at the position where the atom is in equilibrium. If an atom is moved from this position the force tends to restore it; the case is similar to that of a table covered with a regular network of depressions, with a ball lying in each depression. Now consider the force required to move all the balls at once in a given direction, so that each rises out of its hole and falls into the next hole in that direction. It will clearly be the force required to move a single ball multiplied by the number of balls, and this is equally true when a ball lies in every hole and when a few vacant holes are included in the array. The low value of the critical shear stress cannot be accounted for on the basis of the simultaneous movement of all atoms in a glide plane.

The position may perhaps be clarified by considering simply a row of cylinders touching one another, with a second row of cylinders resting on them, as in a model which I have constructed (Fig. 16). The force required to move one whole row over the other is considerable. Suppose, however, that the number of cylinders in the upper row is one or two fewer than that in the lower row. A place of non-fit, or dislocation, indicated by a white line above it, is arranged at one end of the row, towards the right, there being four in the upper row to five in the lower row here. To make the model resemble the atomic case, all the upper cylinders in the model are connected by a long strip of elastic band. If we now run our hand over the upper row, from right to left, which is equivalent to imposing a force from left to right on the lower row, it is easy to make this dislocation travel along. At any given moment we are only moving a few cylinders through the periodic field of gravitational potential. After the dislocation has travelled, however, every cylinder has moved one place, and the whole row is displaced relatively to that below, although at any given moment we were only moving a few cylinders.

The fact that glide takes place at shear stresses so far below the theoretical value shows that a whole sheet of atoms cannot travel at once over a neighbouring sheet. The conception of the glide mechanism, which we owe to Polanyi, G. I. Taylor, and Orowan, postulates that in the metal crystal there are small localities in which the crystal is out of joint, places of misfit something like that represented very crudely in our model. Under shear the whole crystal plane does not move by one atomic spacing simultaneously; rather the misfit runs easily through the crystal, leaving in its wake atoms properly spaced. In a sense, then, the weakness of the crystal is due to imperfections which are somehow inherent in the structure. A perfect crystal might have theoretical strength, but probably no such thing exists.

There is considerable doubt and diversity of opinion as to the origin and end of the dislocations. G. I. Taylor,[33] for instance, when proposing a very suggestive but rather formal two-dimensional model, considers that the stress produces in the metal crystal a multitude of regularly spaced dislocations, which run a certain distance and then end their course in flaws which he postulates. It is difficult to see on this picture anything to prevent the effect being reversible, which it certainly is not. Orowan considers that the dislocations are created at microscopic "Griffiths cracks," sharp notches where the stress has values considerably above the average, and that they run right across the specimen. W. G. Burgers and Kochendörfer believe that the crystal is built up of small blocks in which the orientation of the crystal structure differs slightly from block to block, for which there is X-ray evidence with rock salt and some other crystals. The dislocations are then supposed to start from the boundary of the blocks; how they are stopped is not clear. I have not time to discuss the details and difficulties: the general conception of a travelling misfit seems, however, to be undoubtedly the proper basis for any theory of glide.

Another fruitful conception is that of cracks, notches, or other regions of local peculiarity leading to increased local stress. Thinking of a wooden plant, we may perhaps be allowed to call these hypothetical regions "knots." If these regions of stress concentration are small, the stress will depend upon the irregularities of atomic motion in the neighbourhood—the so-called temperature fluctuations, which are the more violent the higher the temperature. Every now and then the atoms so will dispose themselves that, speaking loosely, the crack is sharper; the longer one waits the greater the chance that the local stress reaches some high critical value. This conception is due to Becker.[34] It has been elaborated by Orowan. The rate of flow of a crystal under stress will be proportional to the frequency with which the critical stress is reached at the local "knots." This leads to the following formula for the rate of glide, u—

$$u = C\, e^{-V\,(R-qS)^2/2GkT},$$

where R is the true critical shear stress, S the average externally applied stress, q a factor to represent the increase at a "knot," G the shear modulus, k Boltzmann's constant, T the absolute temperature, and V a certain small volume, full consideration of which would take us too far.

This formula has certain interesting consequences. It shows the rate as depending very strongly on the stress. According to it, flow should take place at any stress, but if the stress is below a certain value the flow is unobservably small. This is the kind of thing we must expect to find in theories based upon probabilities.

If this view is correct, we cannot define a critical shear stress for a single crystal by saying it is the resolved shear stress at which glide begins to take place, for this will depend upon what rate we are prepared to consider noticeable. I have suggested that we define it as that at which a rate

FIG. 17—LAUE PHOTOGRAPH OF UNSTRAINED SODIUM CRYSTAL

of 1 per cent. per hour takes place. This seems a convenient arbitrary figure, but it is nothing more. The exact rate does not make much difference. In the case of very pure cadmium, considered by Roscoe and myself,[35] stresses of 1·5, 1·3, and 1·0 bar gave rates of 1 per cent. per 13 min. per hour and per seven hours respectively. A stress of 0·5 bar still gave a flow, but of only 1 per cent. in 13·5 days. In the neighbourhood of the suggested rate, with cadmium, for instance, the rate is doubled by about an 8 per cent. increase in the stress.

This way of regarding critical shear stress as the stress at which a determined slow rate of glide begins also explains a remarkable fact, as pointed out by Orowan, who has emphasised the importance of concentrating on the rate of flow as a property of the single crystal. While the rate of flow at a given stress increases very rapidly with the temperature, at a given stage of the flow, and the strain hardening is also very susceptible to temperature, the critical shear stress is not very much influenced by temperature. Even at —235 deg. Cent. it is, for cadmium, only four times as big as it is a few degrees below the melting point of the metal. If we take the critical shear stress to correspond to a fixed value of u at all temperatures, this means that $(R-qS)^2/T$ is approximately constant, which gives $S = A - B\sqrt{T}$, a relation which agrees quite well with experiment.

The difficulty of interpreting curves showing the shear stress plotted against extension ("hardening" curves) will now be clear. If there is a time element, if flow is taking place all the time, these curves will depend upon the rate at which stress is increased. By working within a region where the rate of flow is very small, and applying the stress fairly rapidly, hardening curves with some meaning can be obtained, but sufficient attention has not always been given to this point. The whole

* Institution of Civil Engineers, James Forrest Lecture, 1941.

[33] "Proc.," Roy. Soc. A, 145, 362, 1934.

[34] *Phys. Z.*, 26, 919, 1925.

[35] "Proc.," Phys. Soc., 49, 152, 1937.

question is a troublesome one, complicated by the effect of recovery; that is, a crystal that has been hardened by strain becomes soft again if left to itself at a sufficiently high temperature. For "soft" metals, like cadmium, room temperature is sufficient. Some workers have attributed the time flow entirely to recovery taking place while the stress is still applied; others have tended to neglect it altogether. Actually, true flow in the absence of recovery undoubtedly exists, as can be demonstrated by working at low temperatures, where the rate of recovery must be so exceedingly slow as to be quite negligible. On the other hand recovery undoubtedly plays a part in flow at higher temperatures. Hardening at high temperatures and at low temperatures exhibits different features and requires rather more careful discrimination than has generally been made. The problems of strain hardening can, however, only be glanced at here.

The time element being eliminated as best one can, curves showing the variation of stress with glide[36] at temperatures suitably chosen can be

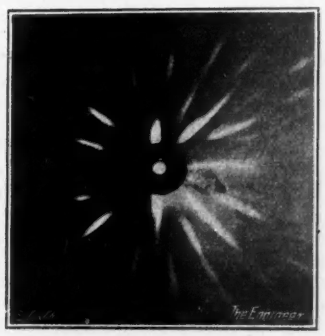


FIG. 18—LAUE PHOTOGRAPH OF HEAVILY STRAINED CRYSTAL OF α-IRON

obtained. Some very striking results are available on metals of comparatively high melting point. Measurements made by Sachs and Weerts[37] and by Osswald[38] show that with a single crystal of nickel a shear strain of 30 per cent. produces an increase of shear strength of fourteen times; with copper a shear strain of 67 per cent. produces an increase of strength of sixty-eight times; while with silver a shear strain of 95 per cent. produces an increase of strength of ninety-two times, all at atmospheric temperature. In many cases the hardening at low temperatures varies as the square root of the glide; at high temperatures it tends to show a linear variation.

EVIDENCE FROM X-RAYS

We have now to consider how this hardening under strain comes about, and here X-rays furnish a valuable method of attack. If we pass a narrow beam of so-called "white" X-rays—that is, a beam containing a wide continuous range of wave length—through a fixed single crystal, each set of crystal planes will reflect the rays at a determined angle, and we obtain, as is well known, a series of spots, the so-called Laue pattern. If the crystal is turned to another position the spots will turn to fresh positions, just as will a narrow beam of light reflected from a mirror if the mirror is rotated, or similarly if the beam passes through two crystals oriented in a slightly different way, the spots will appear double. Now if we take a Laue photograph with an unstrained single crystal, we obtain a pattern of single spots, as shown in Fig. 17,[39] obtained with an unstrained crystal of sodium; but if we strain the crystal the spots are drawn out into smears, called "asterisms," just as would be the case in the presence of a large number of crystals, oriented in slightly different ways, so as to give a train of overlapping spots. Fig. 18,[39] which is a Laue picture of a crystal of α iron, extended by about 16 per cent. shows such asterisms. The heavy strain has produced a change in the crystal structure; in fact, it looks as if the single crystal is strong because it is no longer a single crystal.

With Miss Chow I carried out some experiments[39] on sodium single crystals, extending them by an equal amount at various temperatures and measuring (1) the stress required to produce this extension, (2) the spread of the asterism. It is easy to measure this with sodium, since the asterism takes the form of discrete spots (see Fig. 19), due, as we showed, to recrystallisation. The separation of the extreme spots represents the range of rotation of crystalline fragments produced by stress. These experiments show that at low temperatures, where the crystal is strong, the spread is much greater than at higher temperatures, where it is weak, for the same strain. We have also been able to establish some numerical regularities. I think, then, that there is now definite evidence that the strengthening is largely due, at any rate, to the break-up of the crystal, to a loss of its single-crystal character. Much more experiment is, however, needed to clear up the situation.

POLYCRYSTALLINE METALS

This brings us half-way to real metals, and the problem which interests the engineer, Why are polycrystalline metals strong? There are very few experiments available on the dependence of strength on grain size. In its simplest aspect, this problem demands an absence of plastic deformation, which at once complicates the question; but on the whole it looks as if small grain size is favourable for strength. During plastic deformation slip takes place in the individual crystallites, whose axes are differently oriented, as shown in Fig. 20,[40] which represents a strained specimen of polycrystalline lead. In some way the boundaries between the crystallites must confer strength, but they cannot do it because they are inherently strong—the number of atoms involved is too small. Expressed in another way, the crystal boundaries cannot be regarded as playing the part of the steel rods or expanded metal in reinforced concrete.

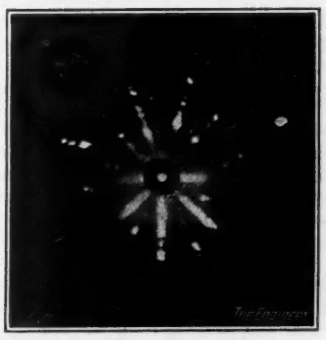


FIG. 19—ASTERISMS DUE TO STRAIN IN A SODIUM CRYSTAL

They are too thin, whatever reasonable strength be attributed to them.

Supposing that, to account for their weakness (low yield point) as compared with ideal crystals, we accept the hypothesis that the crystallites contain submicroscopic flaws, similar to Griffiths cracks in glass, where the stress concentration is abnormally high. If a dislocation runs from such a crack it will travel as far as a crystal boundary and will then find, for a region a few atoms thick, at any rate, a place where the regularity necessary for it to propagate itself is lacking—it loses itself, but not because the boundary is hard; rather because it is soft. An experiment which I carried out some time ago may illustrate the point.

To show the effect of crevasses in weakening a solid, I cut transverse slots in celluloid strips, and compared the strength of these strips with that of other unpierced strips, of equal carrying breadth. The weakening effect of the cuts which was to be anticipated did not, however, show itself. Examination shows that at the ends of the crevasse, where the curvature was greatest and tearing should have taken place, the celluloid had yielded plastically, with slight local deformation made evident by a turbid appearance. The theoretical weakening effect of a crevasse is based upon a postulated rigid behaviour of the solid; if the solid yields plastically, the local stress is dissipated and the tearing does not take place. The analogy is not a perfect one, but does show how strengthening can take place by weakness. Rather large round holes, cut near the ends of the crevasse, in which the high local stress would lose itself when the crevasse yielded, might also be used to illustrate the point.

There is no doubt that the intercrystalline boundaries play a very important part in the strength of metals. However, the experimental study of the properties of these boundaries is only just beginning, and, although Chalmers[41] has carried out interesting experiments on the subject, much work with different metals and at different temperatures is required before we have enough material to found a comprehensive theory. The properties of single crystals of metals may seem curious and curiously remote from anything that the engineer experiences, but it is in terms of their behaviour, and of the behaviour of the less regularly ordered atoms in the boundaries between crystals, that we must seek an explanation of the secrets of the ironmaster and of the worker in non-ferrous metals.

CONCLUSION

I have tried to indicate to you, then, some of the problems which confront us when we try to explain the simplest features of the mechanical strength of solids, such as the tensile strength, the rupture under shear, work hardening, and creep. I have not had time to say much of any of these problems, and if we knew more no doubt my story would have been simpler and more consequential. I have had to lay before you problems which are still in the early stages of attack rather than a compact account of a subject successfully ordered by a comprehensive theory. I would, however, end by a plea that it is a subject well worthy of attention. Even from the industrial point of view, the work which I have very tritely

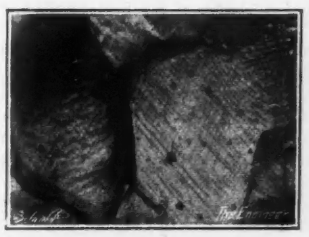


FIG. 20—SLIP IN STRAINED POLYCRYSTALLINE LEAD

and tentatively described is beginning to touch on practice. I have referred to the reinforcing of concrete by glass beams and to hardened glass and glazes, where the state of the surface has had to be considered. I may say also that it has been found necessary to make the tungsten spirals of glow lamps of single-crystal wires, or of wires consisting of very few crystals, for reasons explained by Becker on theoretical grounds, which I have not had time to describe. In a lamp in use, the spirals are above the recrystallisation temperature, and recrystallisation—that is, the transfer of atoms from one lattice to another—is accompanied by marked flow under stress. A single crystal cannot exhibit recrystallisation. It is, however, not on these details that I wish to appeal to you.

After the war there will probably be a great movement for the prosecution of research with an immediate practical end in view, and of the importance of such research there is no question, nor will there be any lack of voices shouting in support of its obvious claims. I wish to enlist your sympathy for the type of research which I have been describing, pursued with the more fundamental aim of finding out the mechanism that underlies certain general properties of matter. The work will be undertaken by men who long to investigate for learning's sake, lured on by the beauty of the phenomena and the hope of finding a meed of that intellectual, nay spiritual satisfaction which attends the understanding of any small sphere of natural happenings—by men who, varying in ability but not in enthusiasm, desire to be natural philosophers, to use the old and choice phrase. The ends are vast, the approach slow.

The ultimate practical gain may be great, for, as we have seen, there are theoretical possibilities of vastly increased strength of materials—where so many of the dreams of inventors are clearly impossible on simple grounds of energy and such-like fundamental considerations, gigantic advances are here, at any rate, not inherently ruled out. Just as the work of J. J. Thomson and his school, carried on without the least thought of practical ends, carried on in the faithful pursuit of scientific truth and beauty, led to the whole modern light electrical industry, so may work of the type which I have glanced at carry in it the seeds of a new metallurgy. I am not suggestiong that any of those who have been working in the field are J. J. Thomsons, or even seconds to J. J. Thomson—far from it. I am not appealing to you on the ground of an immediate or ultimate practical gain. I am begging that if the time comes when you are asked whether any shall be allowed to carry on pure experimental research whither the urge leads them, you shall not ask too strictly whether a practical end is in view, but rather, if you think that they are capable and in earnest, are seriously striving in their small way to advance knowledge, that you shall refresh them and wish them God-speed.

[36] By "glide" is meant the shear strain—the relative movement of two parallel glide planes divided by the perpendicular distance between them. The extension is not a suitable parameter to consider, since it will depend upon the inclinations of the glide planes to the axis in the particular specimen.

[37] *Z. Physik.*, 62, 473, 1930.

[38] *Z. Physik.*, 83, 55, 1933.

[39] E. N. da C. Andrade and Y. S. Chow, *loc. cit.*

[40] E. N. da C. Andrade, unpublished.

[41] "Proc.," Roy. Soc., A, 175, 100, 1940.

Methane as Motor Fuel

"WE owe it to the U.S.A." is a phrase which grows daily in sinister significance as the present war progresses, but we may find relief in the knowledge that our indebtedness to that country for developing methane as a motor fuel is shared by the remainder of the world. Thirty years ago the Americans were content to burn their methane and analogous gases by "torch" on the site of their numerous oilfields. With a growing realisation of the necessity for conserving their oil supplies, in view of the rapidly increasing demand for petrol and lubricants, they began to utilise this natural gas for steam raising at the oilfields and as a motive power for internal combustion engines; but such an outlet employed only a small fraction of the available gas. It then became general to compress the gas into cylinders and so enable it to be transported to distant points to be used either for heating purposes of for powering internal combustion engines. More recently processes have been evolved, both in the U.S.A. and in Europe, which enable methane to be converted directly to liquid motor fuels. In Great Britain the utilisation of methane has reached the compression stage, but no liquid fuels are yet made from it here, which is largely because our known sources of methane have not yet been fully exploited. Such resources comprise its recovery from sewage works, the shale-bearing districts of Scotland, and coal mines. A further source of methane is coke oven gas, which in some British installations is still allowed to burn to waste. In coke oven gas the methane is in admixture with hydrogen and carbon monoxide gas, and it is now being recognised that such a mixture is probably more valuable as a basis in the production of synthetic liquid motor fuels by catalytic processes. This aspect is being studied by the Fuel Research Board and by Synthetic Oils, Ltd.

Methane from Coal Mines

The methane found in conjunction with shale oil and coal does not appear to have been tapped so far in this country. Although it has been recently pointed out by Graham ("Proc.," South Wales Inst. Eng., 55, 326, 1940) that considerable quantities of methane exist in coal mines as fire-damp and its efficient withdrawal would obviously make the mines safer, Graham made tests on forty-nine different coals and states that bituminous or steam coal contains up to 300 cubic feet of methane per ton of coal, whereas anthracite may yield up to 600 cubic feet per ton, the gas pressure within the coal varying from 2 to 8 atmospheres. The bulk of this gas escapes into the mine atmosphere when the coal is being broken up at the seam face. In Great Britain there are approximately 1250 coal mines in production at the moment, of which nearly 500 are large-size concerns, but not all of these are "gassy" mines. To underestimate the number of the latter let us assume that only 200 are gassy mines, each one of which produces 500 tons of coal per day. If this coal, when released at the face, is low in methane content and contains only 100 cubic feet of gas per ton, one colliery yields 50,000 cubic feet of methane per day. The ventilation fans at these 200 mines are thus sucking out of the workings 10 million cubic feet of valuable natural gas every twenty-four hours and flinging it away to pollute the atmosphere. Seventy cubic feet of methane is the equivalent of 1 gallon of high-grade petrol, so every working day we throw away at our collieries the equivalent of 142,500 gallons of petrol, or 4½ per cent. of our total peace-time requirements. The recovery of methane from the mine is not a simple proposition in most instances, for although the concentration of methane at the coal face may be relatively high, it becomes largely diluted with air from non-gassy workings before it reaches the upcast shaft, and its recovery at the top of this shaft through an activated carbon plant, or by other methods, would involve the plant in handling huge volumes of "inert" gas in order to collect a relatively small fraction of hydrocarbon gas. Carbon plants for recovering natural gas in admixture with air have for some years been installed in the neighbourhood of oilfields, so that their installation at coal mines does not appear to present an unsurmountable problem. In some coal mines boreholes exist, but the methane escaping through these is, in general, not utilised, and such holes are regarded only as a means of clearing fire-damp from the mine.

Sewage Methane

So far, in Great Britain, methane has been recovered commercially chiefly from sewage works, wherein it is evolved in the sludge gas during the digestion of the sewage. Sewage works methane contains from 20 to 30 per cent. of carbon dioxide, which, if required, could be removed by scrubbing the gas through water, but in practice the CO_2 is allowed to remain. The recovery of methane from sewage works has up to the present been confined mainly to the South-East and Midland areas of England. In the London area alone at least four sewage works are equipped for methane recovery and are producing on an average about two million cubic feet of methane per day between them. About one half of this output is used in powering the stationary engines at the works, leaving approximately a million cubic feet available for compression purposes. The gas is compressed to about 3000 lb. per square inch into cylinders approximately 8in. diameter by 6ft. in length, one cylinder of gas giving power equivalent to nearly 1½ gallons of petrol. It is usually impracticable, in an ordinary passenger car, to carry cylinders of gas owing to lack of accommodation, although occasionally we see on the roads an enthusiast in a private car with a trailer containing two or more cylinders. The compressed gas is mostly used on the larger commercial vehicles and for stationary engines. It requires little imagination to visualise that if all the important sewage concerns throughout the country were equipped for methane recovery and compression—and such concerns are generally near large centres of population—a good percentage of commercial vehicles could be operated on gas from these methane depôts. This plan has already been partly carried out in Italy, where hundreds of special vehicles for accommodating the cylinders have been constructed at the Fiat works. For the passenger car the use of methane is no more promising than coal gas, for it has to be carried in an unwieldy bag on the roof, and the average bag gives only the equivalent of three-quarters of a gallon of petrol. According to H. T. F. Rhodes, of the Gas Traction Development Committee (*Chem. Age*, 20, 1, 40), the cost of compressing methane, including compression equipment, maintenance and labour, is 2½d. to 3d. for the equivalent of a gallon of petrol; or, estimating all charges, including capital charges, on a basis of an annual production of 150,000 equivalent gallons of petrol, the cost of methane compressed into cylinders—these being included in the capital charge—would be 10d. per equivalent gallon of petrol. This low cost is the result of the Government having undertaken to remit duty on gaseous fuel for a minimum period of five years. Under these conditions, therefore, methane compares very favourably with petrol so far as costs are concerned.

As Motor Fuel

The use of methane in the internal combustion engine has certain advantages over petrol. In the first place its high calorific value of from 21,590 to 24,020 B.Th.U. per pound, or from 930 to 1030 B.Th.U. per cubic foot, renders it an economical fuel in comparison with other gases. It is not essential for a petrol engine to be altered in any way in order to operate on gaseous methane, but in these circumstances the power available would be less than the optimum. To obtain the maximum power it is necessary to raise the compression ratio of the engine. An average petrol engine has a compression ratio around 6 : 1, but the ratio for an average commercial methane is about 15 : 1. The effect of increasing the compression ratio is to increase the power of the engine by approximately one half; or, conversely, a car with a 12 H.P. engine, for example, could be operated just as efficiently by an 8 H.P. engine adjusted to run on methane. In recent years much attention has been given to the so-called "octane number" of a motor fuel. The octane number of a fuel may be defined as the proportion of octane, in a mixture of octane and heptane, which gives the same degree of knocking as the fuel under consideration when tested, under specific conditions, in a C.F.R. (Co-operative Fuel Research) engine. This is a 600 c.c. O.H.V. engine, almost universally used in this country for fuel testing. It has a single cylinder and is usually coupled to a motor which acts as a starter and later to absorb the load. The octane number is therefore really the anti-knock value of a fuel. The introduction of tetra-ethyl-lead and other improvements in the structure of the oil components has done much to increase the octane number of motor fuels. For example, in 1916 the average octane number of a good grade of petrol was 50 to 55 and in 1939 these figures had increased to between 70 and 80. This was before the advent of "pool" petrol, of course. The octane number of a fuel like methane is considerably higher than the best grade of petrol it is possible to produce. The octane values of the higher members of the methane series of hydrocarbons are well established and these numbers are definitely related to the chemical composition of each hydrocarbon. Calculating on this basis—because it is not practicable to obtain an octane number for methane in the usual way—we get an octane number for methane in the region of 180. It is this high octane value of methane which makes possible the increase in compression ratio without the hazard of knocking. Another, perhaps minor, advantage of methane over petrol is that its products of combustion—the exhaust fumes of the engine—are not poisonous, but those of petrol and coal gas are definitely toxic. Compared with coal gas, methane has a higher octane value, will operate efficiently at a higher compression ratio, giving, therefore, more power. A given cylinder space will hold more methane than coal gas. This is because, unlike most gases, the decrease in volume of methane is not proportional to the absolute pressure. As a consequence about 10 per cent. more methane can be accommodated in a cylinder, at a specific pressure, than coal gas.

Liquid Hydrocarbons from Methane

Against the advantages of a gaseous fuel for a motor vehicle is the big disadvantage of having to carry much deadweight in the shape of steel cylinders. This extra weight counteracts, to a large extent, the high efficiency of the fuel. It is not surprising, therefore, to find that numerous efforts have been made to discover practicable means of converting the gas to liquid fuel at normal pressures. These processes have met with considerable success in other countries, particularly America, wherein methane and its analogous gases found in the natural gas of that country are now regularly converted to the liquid product. The plant employed is not nearly so complicated as that used in producing synthetic oils from water gas, for the hydrocarbon methane is already present and has not to be first synthesised. No doubt, ultimately, we shall see plants installed at the larger sewage concerns and at other sources of methane to convert the gas to a liquid fuel on the site, instead of compressing it as is done at present. The liquid fuels so produced from methane have a much lower octane number than the gas itself, but this value is still higher than that of any natural petrol. Typical methods of converting methane to liquid fuel are as follows:—The Compagnie de Bethune, France ("*Brit. Chem. Abstracts*," 116B, 1928), obtains liquid hydrocarbons, the bulk of which distill between 38 and 100 deg. Cent. by passing a current of methane, which need not be pure, over a catalyst of ferric oxide at temperatures between 200 and 600 deg. Cent. According to British Patent 261,267, olefine hydrocarbons are produced from methane by uniformly heating a thin stream of the gas to a temperature of 950 deg. Cent. under a reduced pressure of 20 cm. of mercury, the products of reaction being then cooled suddenly while still under the reduced pressure. A similar method, but at higher temperature, is outlined by Fischer and Pichler (B.P., 316,126), in which methane yields synthetic benzene and other aromatic hydrocarbons by heating a stream of the gas quickly to between 1000 deg. and 1100 deg. Cent. and rapidly cooling, the gas being at the maximum temperature for less than one second. In such a process use is made of a heated quartz tube through which the methane is passed at high velocity to prevent formation of free carbon. In one passage through the tube up to 13 per cent. of the methane is converted to liquid oils consisting principally of benzene and toluene. Hessels, Krevelen and Waterman (*Jour., Soc. Chem. Indus.*, 58, 323, 1939) convert methane into liquid fuels, such as benzene, by rapidly heating the gas to 1170 deg. Cent., the time of contact with this temperature being only 0·06 second. An induction effect is obtained by the use of heterogeneous substances,

such as sulphur and oxygen compounds. A recent U.S.A. patent (No. 2,190,662, of February, 1940) describes the apparatus necessary and details of the conversion of methane and other gaseous hydrocarbons, to higher members of the series, by polymerisation processes, in which adsorbents are used.

There are thus two chief methods of transforming methane to liquid fuel, one being based on altering its chemical structure at a specific temperature, followed by rapid cooling to prevent decomposition. The other method makes use of catalytic agents, in which the methane is polymerised to the corresponding liquid members of this hydrocarbon series. This latter method follows closely that of Fischer and Tropsch for the production of synthetic oils from water gas, details of which were given in these columns recently (see "Hydrogenation and War," THE ENGINEER, page 58 of January 24th, 1941.

Works Surgery and Cleansing Station

IN co-operation with Mr. C. E. M. Fillmore, F.R.I.B.A., the firm's architect, British Timken, Ltd., has recently had a new surgery and cleansing centre built. The former deals with general works needs, whilst the latter is equipped to deal with casualties and personnel contaminated as the result of gas attack. As will be seen from the plan, in addition to the surgery itself, specially constructed rooms constituting the cleansing centre are for the present set apart for ultra-violet ray (artificial sunlight) treatment, available to both the staff and workpeople. The apparatus is easily transportable and the rooms can be cleared quickly in case of emergency. The planning of the building was considerably restricted by the limited space available and the peculiar and awkward shape.

With the works operating at full pressure, twenty-four hours a day, the surgery is on duty both day and night with fully qualified nurses in attendance. In common with other special departments it is air conditioned so that a regular supply of fresh air at the correct temperature is constantly admitted. Sliding partitions, which can be rapidly placed in position, divide it into three separate compartments—a consulting room, where the doctor, who visits regularly, interviews patients in privacy, an infra-red ray treatment room and a rest room. Surgical equipment in the form of sterilising tanks, &c., are electrically heated and thermostatically controlled. Folding stretcher racks are fitted in case it should be necessary to deal with several stretcher cases at a time. The surgery does not only treat cases arising in the works. Workpeople who have been absent from work owing to illness receive "after care" and, if necessary, courses of nourishing extracts are provided. Advice for employees' children who are ailing is also readily given. The directors of the firm believe that to be most efficient and useful to the company and country a worker must be free of home worries as well as work worries. Workers' eyesight also comes in for its share of attention. Persons suffering from headache due to suspected eye strain can have their sight tested free.

The cleansing centre, which has been constructed to deal with every possible eventuality resulting from those kinds of gases likely to be employed in warfare, comprises a series of compartments arranged on the following plan :—

All stretcher cases, both male and female, enter an open shed provided with a door D1, which is closed but not locked, and which leads to the washing room. Passing through the door such cases enter an air lock, females being carried into the washing room through gasproof curtain D2 and males through gasproof curtain D3. The two sliding doors dividing the main surgery from the washing rooms are closed, thus making each room completely private. After cleansing each case is taken into the surgery proper through the above mentioned sliding doors to await transport to hospital. Although considered unlikely, stretcher cases not contaminated may pass through doors D4 and D5, but if gas is employed all personnel will be cleansed. Thus stretcher cases, whether contaminated or not, will always go through the open shed and door D1.

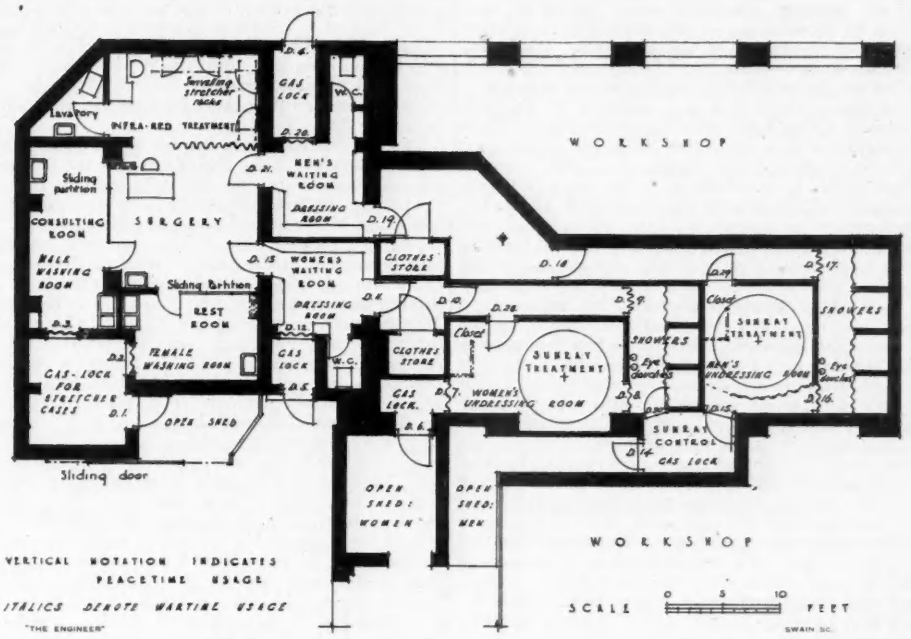
Female cases contaminated by gas, but capable of walking, enter the open shed where outside clothing, is removed and placed in nets ready for cleansing. They then proceed into air lock through door D6 and thence through curtained door D7, where all underclothing is removed. Passing through door D8, eyes are washed and the body cleansed under showers. Exit is then made through curtained door D9, along corridor through door D10, where fresh clothing is provided, passing through door D11 into the dressing room. When dressed, cases pass through curtained door D12 into an air lock and out through door D5. In the event of any cases requiring first aid or surgery treatment, they may enter the surgery through door D13 before leaving through doors D12 and D5.

Similar procedure is adopted for the men, who enter the outer shed, pass through doors D14 and D15 into the undressing room, thence through door D16 to showers, through D17, along the corridor to door D18, leading to stores for clean clothing, and thence through door D19 to the dressing rooms, finally passing out by doors D20 and D4. Those requiring treatment enter the surgery through door D21 before passing through the air lock D20 and D4.

Persons not contaminated by gas, but suffering from some form of injury, enter through doors D5 for women and D4 for men, and use their respective dressing rooms as waiting rooms while awaiting their turn for treatment. Access to the surgery is by doors D13 and D21 respectively. Exit is made by reversing the above route.

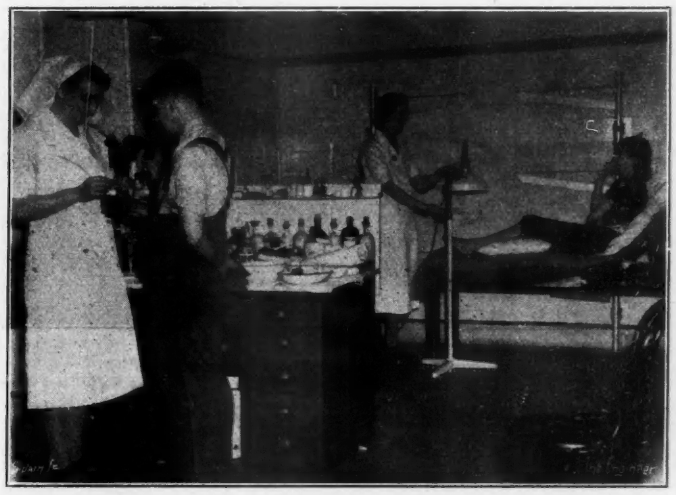
Doors D28, D29 and D30 are permanently closed during the above operations, only having been constructed to facilitate entrance to the undressing rooms for persons taking artificial sunlight treatment. These rooms would, of course, be cleared of all such apparatus in the event of a gas attack.

The cleansing centre described above is at the present time used for artificial sunlight treatment and houses the required apparatus. It will be noted that the rooms are both closely linked with the surgery and dressing rooms. The doctor examines the workers and prescribes treatment, which is given by fully qualified supervisors. The patient begins with a sitting of about four minutes' duration, which is gradually increased to twenty minutes over the four to six weeks' course. The ultra-violet ray lamps are placed in the centre of each of the rooms, and white rings, painted on the floor, serve as a guide to the intensity. As the course progresses the worker moves inward from the outer circle. Careful records are being kept to test the beneficial effects of the treatment. Views in the surgery and of artificial sunlight treatment are reproduced.



PLAN OF WORKS SURGERY AND CLEANSING STATION

ARTIFICIAL SUNLIGHT TREATMENT



VIEW IN THE SURGERY

FOUNDRY SAND.—In the course of a paper on sand submitted to a Canadian foundry association, emphasis was laid on the control of moisture content. While no general rules could be laid down, there was an ideal moisture content for every sand, which resulted in the best combination of strength and permeability. Generally, the finer the sand and the greater the amount of clay used with it, the higher the percentage of moisture required. A sand with 10 to 15 per cent. clay needed 5 to 7 per cent. moisture, while with a bond of about 4 per cent. bentonite, 2 to 3 per cent. moisture might be sufficient.

New American Shipyards

IN a Journal note of December 27th, 1940, we recorded the announcement of Mr. Ronald Cross, then Minister of Shipping, that an order for sixty merchant ships had been placed by the British Purchasing Commission in America and that United States shipbuilders were working out a scheme for mass production, whereby the order given would be completed by the end of 1942 or within about eighteen months of the laying of the first keel. Work was started on the construction of the new shipyards within ten hours after the signing of the contract.

Particulars have now been released of the new shipyards which have been laid down by the Todd Shipyards Corporation, of New York, and are operated by two subsidiary companies, the Todd-Portland Shipbuilding Corporation and the Todd-California Shipbuilding Corporation, of Richmond, California. Preliminary particulars of these yards, which are already in production, have reached us, and later we hope to give still further details of these interesting plants.

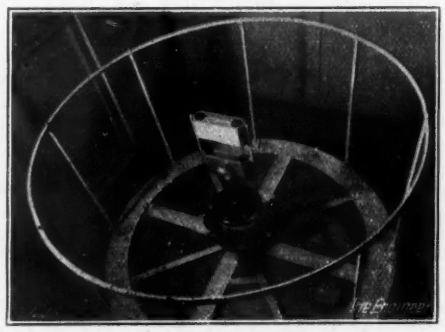
In an accompanying engraving we reproduce a view of the yard at Portland, Maine, which is now in an advanced state of construction, permitting the assembly of hull frames and bulkheads. It is, we learn, proposed to construct six or seven berths at each yard, which will be complete with plate and assembly shops, a mould loft with template stores, a machine shop, a welding shop with oxygen and acetylene generating plants, a pipe shop and stores. The type of ship to be built in these yards has been decided upon by Sir Amos Ayre, Deputy Controller of Merchant Shipbuilding and Repairs and Director of Merchant Shipbuilding at the Admiralty, and on the American side the British Purchasing Commission has, we understand, collaborated with Messrs. Gibbs and Cox, naval architects, of New York. The ships will have a length between perpendiculars of 416ft., an extreme breadth of 57ft., and a depth to shelter deck of 37ft. The deadweight carrying capacity will be about 10,100 tons, corresponding to a gross tonnage of round about 7300. The propelling machinery will comprise modernised reciprocating engines taking superheated steam from Scotch marine boilers. Further particulars of the engines and the probable speed of the ships must for the time being remain in abeyance. We are given to understand that the machinery and boilers will be built in various plants in different parts of the United States and will be sent on to the shipyards for assembly and erection in the ships.

A further engraving accompanying this article is an aerial view of the yard at Richmond, California, at which work is also well advanced, the keel of the first ship having been laid down on Monday, April 14th. This yard is constructed on an advantageous site between the Lauritzen and Parr canals, the berths facing the Santa Fe channel.

The berths are seven in number and are placed at a slight inclination to the line of the pier, the outboard ways being extended into the deep water in front of the berths. Between the berths there is a crane track consisting of a concrete apron supported on sets of triple piles, on each side of which are assembly platforms carried on further piling. Work on the dredging of the site was begun on January 30th, 1941, and pile driving was commenced a few days later. By March 26th 500 piles were being driven daily. The work of excavation was carried out with the latest design of American contracting plant, including excavators, bulldozers and motor lorries, and trucks drawn by oil engine driven locomotives. In addition to the work on the berths, construction was begun of the plate shop and assembling bay, shown in the accompanying engraving, and also the machine shop, in which machine tools were erected, while the concreting of other parts of the shop was proceeding. Other buildings include the mould loft and template store, which was so far completed as to enable work to be begun on templates by the end of April. Additional buildings in the yard include a commodious office, a general stores, pipe and plate stores, and oxygen and acetylene generating plants for welding, which will be freely employed in the construction of the hulls. Already in the early part of April the steel had been delivered for the fabrication of steel structural members for bottom shell plates, the inner bottom structure, and side frames and bulkheads. The information which has so far come to hand, and has been made available, shows that no effort has been spared to speed on the progress of the work and to advance the first ships towards the important stage of launching. At a later date we hope to be able to publish further details of these two new American shipyards, which are devoted to the building of merchant ships for Britain.

Works Artificial Sunlight Treatment

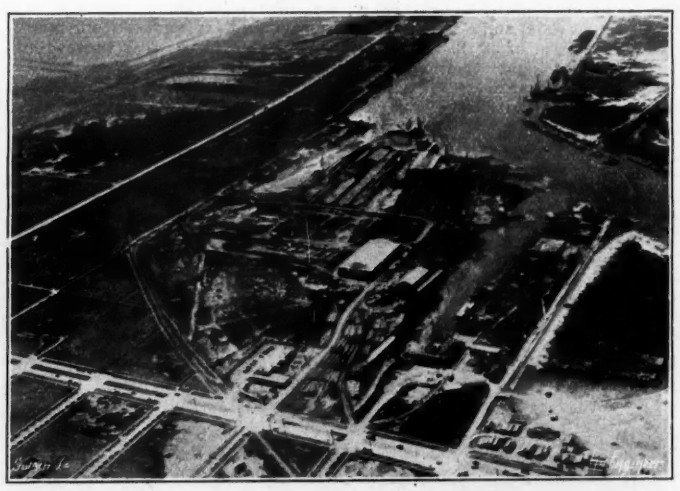
WHILST it is well known that hospitals have used ultra-violet rays for many years as a cure for various ills with beneficial results, it is not generally realised that these rays may be employed as a tonic and a safeguard against illness for a large number of people, especially factory workers, who, as a result of war-time conditions, have to bear a severe strain. The lamp is of such power that three mintues' treatment is equivalent to twelve hours' sunshine, and it is claimed that the ultra-violet rays form vitamin D in the system, tone up the blood stream, increase the resistance to infection such as the eommon cold or influenza, improve muscular energy, and result in lessening of fatigue.



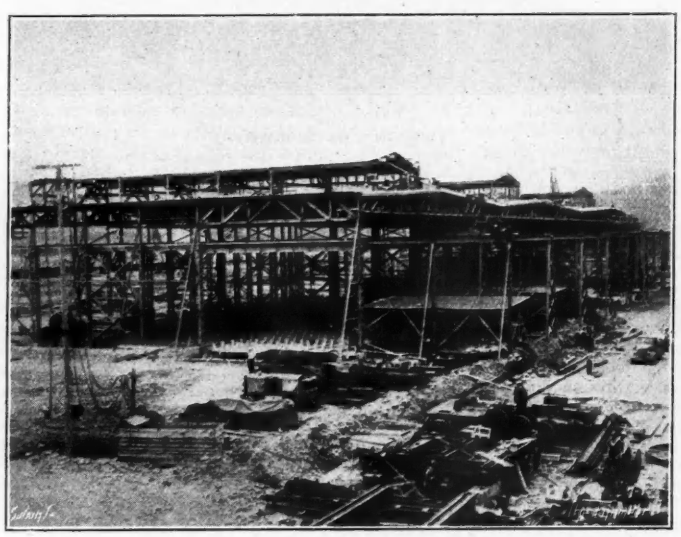
ARRANGEMENT OF LAMP

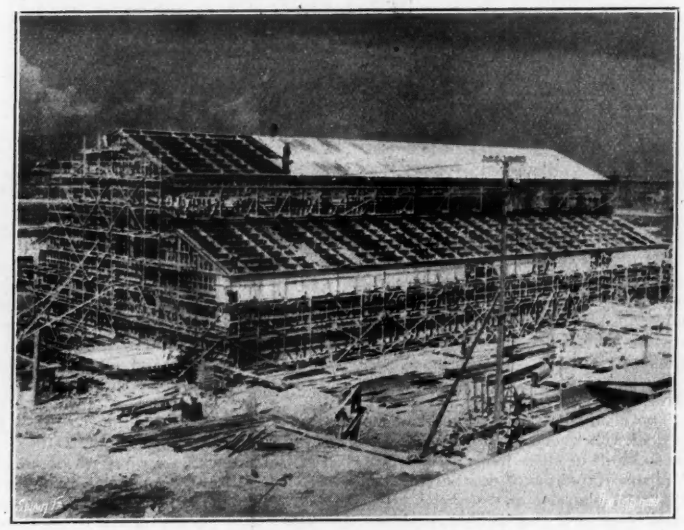
Guy Motors, Ltd., Wolverhampton, have now had two winters' experience of giving artificial sunlight treatment to the staff and employees. The treatment

CONSTRUCTION OF PORTLAND SHIPYARD



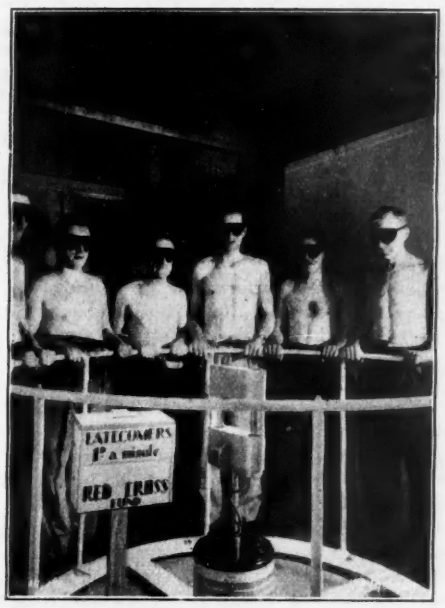
AERIAL VIEW OF RICHMOND SHIPYARD





ERECTION OF PLATE YARD AND MACHINE SHOP AT RICHMOND SHIPYARD

is purely voluntary and the applicant must first consult the works doctor, who certifies whether he or she is in a fit condition. Actually there are very few cases in which the treatment would be harmful. After a free examination the applicant is ready to take the treatment, which commences with 1½ min. front and 1½ min. back. This is continued twice a week for the first eight weeks. Then after a week's rest the course is continued. The time is then increased to 2 min. back and 2 min. front—the maximum time allowed. It must be stressed that nothing curative is attempted and the treatment is purely the application of a tonic ray. The treatment is usually carried out at 3ft. from the lamp, and to guarantee that the patients do not get any closer, a guard rail was introduced, as can be seen in the illustrations. One lamp will treat twelve people at the same time, and an endeavour is made always to keep them in the same group. The time at which any particular group should go for treatment is announced 5 min. beforehand over the loud speakers, and to avoid the group being held up by late comers, they are expected to contribute 1d. for each minute they are late to the Red Cross box as penalty. The maximum time that anyone is away from their work is 10 min., and as evidence of the popularity of the sunray at Guy Motors, records show that less than 1 per cent. of the people who



ARTIFICIAL SUNLIGHT TREATMENT

have taken the treatment have dropped it. This last winter's records, the firm states, show that of those who attend the treatment, only 3 per cent. are absent through illness, whilst for those who do not attend the sickness figures amount to 10 per cent.

The ray is closely comparable to the ray of the Alpine sun. That is to say, it gives very little heat but penetrates to the blood stream. From the general psychological point of view, sunshine is synonymous with heat, and to give this effect a subsidiary infra red installation is sometimes used. There are two mercury vapour quart tubes of 1000 watts each in each unit. On switching on the current the ray commences, but does not give full power until 2 min. have elapsed, and during that time there is an emission of ozone. It has a strong, but not unpleasant, odour, similar to the smell of seaweed on the beach. On damp mornings the ozone may become obnoxious to the patient, and two extractor fans have therefore been fitted, which also act as air purifiers. They are controlled by the operator.

The operator keeps the records of attendance and sees that the heat of the room is kept at 60 deg. Fah. Mounted above the panel above the control desk are two second clocks, one for each cubicle, indicating in minutes and fractions of minutes. A bell informs the operator when to tell the patients either to turn round or to finish their treatment. There is also a bell push fitted to the cubicle door which is pressed by the last man of the group to enter, and this gives the operator the cue to start the second clocks.

American Engineering News

Economics in Airport Design

With the rapid increase in aeroplane traffic in the United States many of the municipal or civil airports need extensive improvement and enlargement, although in some cases enlargement is impracticable owing to neglect of certain factors in the original design. A recent report states that the future growth of air travel and use of the air is purely guesswork, and that the development of the railway and the motor vehicle offers no basis for evaluating the growth of air travel. However, certain curves developed from early air traffic records and beginning with 2,130,000 passengers in 1939, show estimates of 10,950,000 for 1945 and 30,000,000 passengers for 1950. Similarly, light freight or parcels business based on 3130 tons in 1939 is estimated to reach 16,240 tons in 1945 and 45,000 tons in 1950. From a study of some 800 airports it appears that 66 per cent had runways 2000ft. to 2500ft. in length and only 1½ per cent. had runways of 5000ft. or longer. In view of the large investment represented in airports, it is thought that even where extension is practically unlimited it is not likely that the 5000ft. length will be exceeded, even for important airports. Furthermore, in view of the utilisation of multi-engined aeroplanes, the prevalence of wing flaps and the possibility of other improvements in aeroplanes, the conclusion is that 5000ft. probably will be the maximum size required in the future for airports. However, Government plans for civil airports are based on a typical area one mile square. Designers of aeroplanes must produce aeroplanes that can use fields of this maximum length. Such a field could handle traffic up to the limit of twenty-four aeroplanes per hour on a single-width runway. Hangar area for important airports should be from 50,000 to 75,000 square feet.

Regulations for Military Roads

In developing a complete system of roads for national defence requirements, and capable of carrying modern mechanised military equipment, the Public Roads Administration of the United States Government has prepared new specifications which provide for the heavy loads imposed by tanks and gun carriages, and for the greater widths necessary to permit military convoys to travel without serious interference with ordinary traffic. For 20-ton tanks, with 10 tons on each "crawler," these crawlers have 12ft. length of ground contact or bearing, a width of 14in., and a transverse spacing of 7ft. between centre lines. For 55-ton tanks, each crawler has a bearing length of 16ft. and a width of 27in., while the spacing between centre lines is 8ft. The 20-ton typical tank is 17½ft. long overall and 8½ft. in extreme width; for the 55-ton tank the figures are 25ft. and 10½ft. respectively. Typical motor lorries of 10 and 20 tons loaded weight have 8 and 16 tons on the rear—driving—wheels and 2 and 4 tons on the front wheels. The wheel base is 14ft., and the wheels are 6ft. apart between centre lines of tyres. For the tyres on the driving wheels the width of each tyre is equal to 1in. per ton of total loaded weight, or 20in. for a 20-ton truck. For two-lane roads the minimum paved width should be 18ft., but on new construction it should be 20ft., where the daily traffic does not exceed 600 vehicles, and 24ft. for heavier traffic. To permit parking on roads carrying more than 1800 vehicles daily, there should be shoulders at least 8ft. wide. If such continuous shoulders are not practicable, they should be provided in lengths of 2000ft. at intervals of not more than 4 miles. Gradients on new roads should not exceed 1 in 16·6, in mountain country, and 1 in 25 elsewhere; these will permit passenger motor vehicles to travel at 60 and 70 miles an hour, respectively while lorries and tractor-trailers can travel at 15 to 25 miles an hour.

American Military Roads

Although no new system of highways is necessary for the military defence programme now being formulated in the United States, there is much need for heavier construction on a large but scattered mileage in order to carry modern mobile military equipment. This applies especially to secondary roads. New construction is needed for access to the camps and training areas now being established, and also to the many new industrial and manufacturing plants. At the annual meeting of the American Road Builders' Association it was pointed out that construction and improvement work which is of particularly military usage should receive a larger amount of financial aid from the Federal Government. One great difficulty in securing sufficient funds for the necessary programme of expansion is the lack of definite knowledge as to the resultant public benefits. A first step is to induce Congress to appropriate sufficient funds for building new access roads to camps and training areas. Next to this is the provision for preventing congestion of traffic around the various plants working on orders for military equipment. As to bringing the strategic system of highways up to the construction standards necessary for military traffic, the trouble is that no definite standards exist. Some of the State Governments consider that their own standards are sufficient for their traffic conditions, and if higher standards are required for military traffic the cost of such heavier construction should be provided by the Federal Government. As yet, however, the military authorities have not announced what is required, nor has Congress taken any action. Another difficulty is the potential shortage of labour, which means a wider use of mechanical equipment and the introduction of improved machines, although some manufacturers are hampered by their work on orders for military equipment.

A Double-leaf Swing Bridge

A novelty in swing bridges is a recent structure over the Inland Waterway Canal, which consists of two leaves or sections, each mounted on a central pivot and their ends meeting at the middle of the waterway or channel. This unusual design was adopted to meet conditions of skew crossing, highway approaches and under-clearance, the two spans or leaves being of the through-girder type, each 140ft. long over all. The cost was estimated at £27,000, as compared with £30,000 for a double-leaf arrangement with unsymmetrical leaves, £31,500 for a vertical lift bridge, and £34,000 for a double-leaf bascule bridge. An important item in the economy of the adopted design was the fact that the shore half of the span serves as an approach span and also as a counterweight for the cantilever half of the span extending over the canal. There was also a saving in pier construction, counterweight, superstructure, machinery and power. Dead load is reduced by means of a light-weight floor consisting of a steel grid filled flush with concrete. Maximum deflection at the centre, with shear lock closed and the two cantilever arms acting as a single span, was estimated at 3in., and there was some fear that such deflection might produce enough vibration to be noticed by passing motor vehicles. However, with the bridge in operation no such vibrations have been experienced. A 10 H.P. electric motor with speed reducing gear drives a single pinion engaging a rack with internal gear. A 5 H.P. motor operates the centre shear lock, centre wedges, latch and end wedges, this motor operating through a speed reducing gear of 25 to 1 ratio. An unusual feature is the application of a manually operated greasing system for the lubrication of all moving parts and all bearings. From the pressure pump copper tubing runs to regulating valves at all lubricated parts. One of the design problems was to work all the machinery and equipment into the limited space available.

American Steel Works Expansion

Not all the extensive developments of steel works in the United States are being made by the great concerns. Typical of numerous improvements at the smaller plants is the construction of a new three-high sheet mill for the Continental Steel Corporation to roll sheet bar breakdowns in pairs. Novel improvements include a high-speed worm reduction screw-down gear having automatic control mechanism to determine the pass setting for three to nine passes. This is expected to increase production by 20 per cent. over the older hand screw type of gear. With automatic roller and catcher tables this mill can roll an average of 80 tons per eight-hour shift. The bars are delivered in pairs from a continuous furnace, 80ft. long, and after two single passes they are given sufficient matching passes to bring them to the required gauge. Bars up to ⅝in. are rolled down to 0·109in. in five passes. The bottom roll, with roller bearings, is driven by power at 30 revolutions, the others being revolved by friction. Water control stations control the shape of the bar without crowning or convexing the middle roll. A quick-action pneumatic mechanism provides for changing the middle roll in four minutes as a maximum. To meet the increasing use of stainless steel in household furnishings and equipment the Rustless Iron and Steel Company has enlarged its plant to an annual melting capacity of 75,000 tons, with production on the straight-line system, as in the manufacture of automobiles. Ingots are rolled to billets, conditioned and hot rolled into bars and wire. With two 16-ton furnaces added in 1940 the capacity is now 75,000 tons; while other new equipment includes a 28in. mill, a three-stand 12in. mill, and a seven-stand 9in. mill for producing bars and coils. The company's processes permit direct reduction from chrome ore to produce the chromium which gives the steel its distinctive properties. In a building 1800ft. long ingots enter at one end and finished bars and wire emerge at the other end. The capacity of output is 18,600 tons annually.

BRITISH STANDARDS INSTITUTION

All British Standard Specifications can be obtained from the Publications Department of the Institution at 28, Victoria Stree, London, S.W.1. The price of each specification is 2s. 3d. post free, unless otherwise stated.

ELECTRIC TRACTION MACHINES

No. 173—1940. There has been a standard specification for traction motors for many years, but not for the various other rotating electrical machines forming part of the equipment of electrically propelled rail and road vehicles. These machines are now, however, included in a new specification recently issued, which also contains a revision of the specification for traction motors. This new specification covers the classification, rating and methods of test for A.C. and D.C. traction motors, main motor generator motors, main generators, auxiliary motors, auxiliary generators and dynamotors, phase converters and D.C. converters. Appendices to the specification deal with the standard methods of determining efficiency and the losses in the driving mechanisms. It is understood that in the drafting of this specification there has been close collaboration with the International Electrotechnical Commission.

The Engineer

JUNE 20, 1941

VOL. CLXXI No. 4458

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THE DESIGN OF CONDENSING PLANT

THE designer of condensing plant is confronted with only one factor outside his own control, namely, the average temperature of the cooling water supply. Subject to the limitations that this temperature imposes, he is free to decide on what vacuum he likes, and can then provide such cooling surface, quantity and velocity of circulating water, and number of passes as he considers most appropriate. In practice, the vacuum will be settled in accordance with the wishes of the turbine designer; the tube diameter will be decided in view of the size of the condenser, and the nature of the circulating water; a provisional water velocity will then be assumed, and the number of variables reduced in this way until a satisfactory design can be arrived at by a process of trial and error. The result, especially if obtained by a man of experience and judgment, may well be an excellent condenser. But there will always be the question whether some alternative design involving perhaps a slightly higher or lower vacuum, an alteration in the quantity of circulating water, a different number of passes, or some other modification, might not have produced an even better compromise between efficiency and cost. Every fraction of an inch of vacuum has a certain monetary value, depending on the conditions of the plant. Against this value must be set the cost of obtaining it. There will always come a point when any extra expenditure on tube surface, pumping power, or cooling towers will equal the value of the extra vacuum thereby procured. The real duty of the designer is to approach this point as closely as possible, keeping, however, always on the safe side of it, because once money is spent it is gone, whereas the anticipated benefits may prove illusory.

While no engineer would deny the truth of this proposition, it would appear from most of the books and papers about condensing plant that it has been generally overlooked, the writers being often too preoccupied with the relative merits of different tube patterns and similar details to give their attention to the fundamental principles of economical design. Consequently, rules of a "pocket-book" nature have grown up, such as, for example, that it did not pay to aim for a vacuum temperature within 22 deg. Fah. of that of the inlet circulating water, or that it was profitable for the quantity of water to be kept to a minimum, and its temperature rise to a maximum. Such rules are no doubt correct in special cases, but they have no general application. It almost seemed that for some years condenser design had been getting into a rut, and its broader aspects neglected, possibly on account of an idea that there was nothing fresh that could be said on the subject. This reproach has, however, been definitely removed by the masterly and original paper recently read by Mr. W. T. Bottomley before the North-East Coast Institution of Engineers and Shipbuilders, which we are reprinting. In it the author sets himself to examine all the factors upon which the cost of a complete condensing installation depends, with the object of determining the conditions that would give the best value for the money spent. The reasoning is mathematical throughout, and often of admirable ingenuity, especially when certain intractable relationships had to be reduced to a workable form without any appreciable sacrifice of accuracy. For details of the argument, reference must be made to the paper itself, as it does not lend itself to a general exposition. The conclusions likely to attract the most attention are that in base-load stations with a good load factor it would pay to reduce the ordinary rate of condensation by 25 per cent. and to reduce the usual velocity of the water in the tubes by something like 30 per cent. Mr. Bottomley's calculations convince him, not merely that condensers in general should be larger, but that, when the dimensions of the engine-room are already fixed, the size of the condensers can profitably be increased up to the limit of space available for them in the building. The economical water velocity is shown to be independent both of the extent of the cooling surface and of the quantity of the water, while the economical ratio of water to cooling surface is independent of the vacuum. The latter ratio, which governs the number of passes and the length of the tubes, depends upon the length of the circulating water mains. When these are very short and there is an ample water supply, single-pass condensers may be advantageously used, whereas at least three, and sometimes four, passes should be adopted in stations depending on tidal waters or on cooling towers.

It is worth while repeating that Mr. Bottomley's paper is not concerned with what may be called the technical efficiency of condensers, but rather with that balance of design which will conduce to the greatest financial returns for the money spent on the whole condensing system. This is a broader view than that taken by the ordinary designer, whose main object is to provide the least expensive condenser that will perform a given duty. The difference in outlook no doubt accounts for Mr. Bottomley's conclusion that condensers might profitably be designed on a much more liberal basis than most manufacturers would consider adequate. The many operating engineers who, as he says, call for larger condensers will be gratified to know that their desire for very easily rated cooling surfaces, that will only get dirty very slowly and even when foul will still give a reasonable performance, is justified by reasons of financial economy, as well as of practical convenience. It may be too much to expect that all of the many important conclusions arrived at by Mr. Bottomley will command universal assent, but his reasoning is cogent. Moreover, the monetary values which he ascribes to the variable factors are clearly stated, so that other values can be substituted if desired. His paper breaks new ground, and is likely to rank as one of the most suggestive and valuable contributions to the design of condensing plant.

Stability of Suspension Bridges

THE faith of the public in suspension bridges has probably been a little shaken, especially in America, by the recent failure of the Tacoma bridge and the disclosure that movements similar to that which brought about its destruction have been observed and have required correction in other similar structures of recent date. The tendency of suspension bridge design in America has been, for the last twenty years at least, towards higher span-to-truss and span-to-width ratios. In the Tacoma bridge those ratios were pushed very much higher than they had been in any other bridge. Thus, though that bridge cannot be regarded as truly representative of modern design, and though the fact that the Whitestone, Thousand Isles, and other bridges have responded to methods of stabilisation indicates that elsewhere the tendency has not been pressed too far, the failure at Tacoma provides a warning that the theory of suspension bridge design needs some correction before any further advance in those ratios can be safely made.

The immediate cause of the disaster—the spark that lit the fire—was, according to a report by a Board appointed to inquire into the matter, the slippage of the centre cable-band on the north cable. That band was connected by short diagonal ties to the stiffening girders, an arrangement adopted in several modern bridges to reduce vertical oscillations. But whereas in other bridges such ties are pre-stressed to a considerable tension, the tension in the Tacoma structure seems at the time of the failure to have been merely nominal. As a result, when vertical oscillation occurred in the bridge deck, a movement in itself not regarded as dangerous, the ties alternately slacked off and retightened. In such circumstances the slippage of the cable band cannot be regarded as altogether surprising. As soon as it occurred, the vertical motions of the two cables were thrown out of step and torsional oscillation was set up and grew in vigour to such an extent that one of the suspender cables broke under impact loading and others followed in succession, until a large part of the deck fell into Puget Sound. If that were the whole of the truth there would be little cause for concern. But the Board also came to the conclusions that even had the diagonal ties been sufficiently tightened, the bridge would still eventually have failed; that diagonal stays from the tops of the towers, such as have proved effective on other bridges, would not have provided sufficient rigidity; and that tie-down cables under the side spans would only have reduced the motion in those spans and would not have acted effectually upon the main span. For the bridge it seems was so inherently inclined to torsional movement that it must inevitably have failed sooner or later from that cause, and though statically designed, in accordance with the knowledge available at the time, to resist a 100 m.p.h. wind, it was aerodynamically unable to resist a wind of anything approaching that force. The Board adds the interesting warning that above a certain wind velocity any suspension bridge tends, once torsional oscillation has started, to build up an increasing movement. As might be expected, the narrower the bridge, the lower becomes the initiating wind velocity. Thus the Tacoma bridge, with its high span-to-width ratio, was particularly susceptible.

It is easy to be wise after the event. But it is worth pointing out, as one of our transatlantic contemporaries has done, that the tendency of suspension bridge design in recent years has been towards a type which suffered many disasters in the past. The Board itself comments that it does not seem to have been realised that, though lighter spans have been wrecked by aerodynamic forces in the past, those forces could affect a structure of such size as Tacoma. Early suspensions, such as those built by Finley in America, had substantial stiffening trusses. In effect, they were almost girder bridges made capable of carrying greater loads by the support of chains. It was in the natural course

of development that the girder should be discarded and the whole of the load be assigned to the chains. But the result was disastrous. In this country, Sir Samuel Brown's bridges at Berwick and Montrose were wrecked by wind, and it is possible that a similar cause was at least partially responsible for the failure of his famous chain pier at Brighton. In America, Eller's 1100ft. span Wheeler bridge suffered a fate which, according to contemporary accounts, seems to have been an almost exact parallel to that of Tacoma. There was trouble even with Telford's Menai bridge. All these structures were erected before the theory of the design of suspensions had been worked out. W. J. M. Rankine seems to have been one of the first to direct attention to the importance of the stiffening truss. But even before his work was known in America, Roebling had gone back to the use of it, and it has seldom been omitted since that time. Recently, however, there has been a progressive return towards the less rigid type of bridge. It is a tendency that has led to a general lightening of the whole structure, and has made it possible to span greater lengths at reduced cost. But the inherent danger of thus lightening the structure seems, at least in the bolder recent designs, to have been overlooked. Since the failure of the Tacoma bridge it has been suggested that such spans should be aerodynamically designed for stability under wind pressures, and thought has also been stimulated towards the development of light structural methods of achieving greater rigidity. But even if such schemes turn out to be impracticable, engineers are hardly likely to be frightened into a return to the heavy stiffening girders of the past in the search for safety. The advantages of the tendency of modern design are far too great to be set aside unless it proves impossible to achieve the necessary stability in some other and preferable manner.

Literature

Construction Planning and Plant. By ADOLPH J. ACKERMAN and CHARLES H. LOCHER. McGraw-Hill Publishing Company, Ltd. 1940. Price 28s.

IN the last decade there have been under constructing in America a remarkable number of immense public works requiring for their successful completion at reasonable cost to public funds the building up of great, but temporary, organisations. The authors of this book, the first a civil engineer and the second a veteran contractor, were both concerned in the works constructed in the Tennessee Valley, works which have been described at length on more than one occasion in THE ENGINEER, the one as head construction plant engineer and the other as construction consultant. The contents of this book, which appears to have been written mainly by Mr. Ackerman, but with the constant advice and help of Mr. Locher, first appeared between November, 1935, and March, 1938, as a series of articles in *Construction Methods*, and they have since been brought up to date.

It would take too much space and prove tedious to mention at length all the matters that are dealt with in this book. The first fifty pages or so are devoted to such subjects as the general problems of constructional jobs, the preliminary planning, preparatory work at the site, and the construction stages, including the programming of the job. Thereafter the various types of equipment and their characteristics and methods of use are discussed with insight drawn from the authors' actual experience. A particular point is made of the importance of measuring performance and means are suggested and described for doing so. In addition, chapters are devoted to such subjects as the design and construction of cofferdams, the diversion of rivers, cut-offs, pile foundations, and caissons. The book closes with a chapter entitled "Human Relations," in which it is stressed that it is a positive advantage to provide comfortable quarters and living conditions for those "on location."

Since its authors have had particular experience in that field, the book is particularly—in fact, almost entirely—concerned with the construction of dams and their associated hydraulic works. But the principles which are brought out regarding the mechanisation of operations and the scientific control of all operations apply with equal force to other types of work. Though the book is based particularly on experience in the Tennessee Valley, methods used elsewhere are not neglected. "If this book," says Mr. Ackerman in his preface, "succeeds, first, in offering a useful reference for the construction man, and, second, in pointing out to what extent construction is an art capable of scientific analysis, the effort required to prepare it has been worth while." But though one of the main objects of the book is thus to explain how scientific analysis can be applied to the multifarious operations connected with the construction of public works, Mr. Ackerman recognises that it can never become complete. "Construction will always remain an art, because to its science must be added the experience, ability, ingenuity, imagination, initiative, co-operative effort, and courage of the practical builder. Every man, from the waterboy to the President, contributes his share in providing such qualities, and these do not come from 'book-learning.'"

Canning Practice and Control. By OSMAN JONES, F.I.C., and T. W. JONES, B.Sc. Second edition. London: Chapman and Hall. 1941. Price 32s.

A CHARACTERISTIC of this book is the documentation. Every chapter ends with a bibliography, and the items sometimes run into high double figures. In some chapters the authors rely almost wholly upon the published results of research workers. This raises an interesting question. When knowledge is complete and final, it is accepted by all, and bibliography is only of historical interest. Is it true, conversely, that when authors deem it desirable to justify statements by literary references, doubt still exists? Furthermore, is there not a danger that readers may be misled, if they be not wary, by the pseudo-authority which a bibliographical footnote imparts? Everyone of us thinks he has confirmed the accuracy of a statement if he can quote the author of it. Of course, there is no justification for that faith. A wrong statement is not made right by attaching a name to it. To be of any value, the authors classified in a bibliography must be persons of recognised reliability. It may be, we hope it is, that the Messrs. Jones have satisfied themselves that all their references are to unchallengeable sources. Authors cannot shelter themselves behind quotation marks and bibliographical reference numbers. If they are unable to make statements on their own responsibility, they must satisfy themselves at least that the authorities they quote are unimpeachable. Assuming that our authors have done so in this case, then the copious bibliographies add to the value of an already valuable work.

It is only a few years since the first edition of this book appeared. The exhaustion of that issue and the call for a new one indicates at once the importance to which the canning industry has grown in this country—for this is an English book—and the number of people who are taking an active interest in the technical and scientific problems which it presents. "Canning" means the preservation of foodstuffs in appropriate containers, generally metal or glass, by heat treatment. Over 350 different canned foods are now available on the world market. They may be divided broadly into two classes, those primarily composed of animal tissues and those composed of vegetable tissues, but there is overlapping in the case of soups and made dishes. In 1922 there were in the United Kingdon ten firms engaged in fruit canning and bottling; seven years later the number had risen to eighty-three. Then a setback occurred, and in 1935 only seventy-three firms were canning fruit and vegetables. This falling-off was due in part to the familiar over-swing of the pendulum, and in part to insufficient knowledge and a lack of experienced operatives. Needless to say, these figures are far below those of other countries—for the United Kingdom is a consumer of foods produced elsewhere. In the United States, to quote a notable example, there are over 2000 canning firms, and the number has been as high as 2535—as against our 73.

Owing to the relatively small size of the canning industry in Great Britain, knowledge of it is reserved to the select few who are engaged either upon the purely technical work of canning factories or in the chemical and biological laboratories which are imperatively necessary adjuncts of canneries. Hence the attraction of a book like this to anyone who has the desire to know about things, even though they do not concern him directly. For the authors go through the whole business from A to Z, often entering into details—as, for example, on microscopical examination—in a manner that must be useful and interesting to the professional "canner." It is perhaps indicative of the remarkable care that is taken over the preparation of canned food that well over half the volume is devoted to the cannery laboratory and the multifarious aspects of its work. At every stage of canning pains must be taken to exclude things that may be injurious in themselves to human beings or may cause poisons to be built up in the course of time. The containing vessels, the materials used, in some cases, to line them, the water, even the air itself, may call for just as close attention as the raw materials—fruit, vegetables, meat, and fish—that are canned. One long chapter—too technical for the ordinary reader—is devoted to the principal food-spoiling organisms and their detection, whilst another, of more homely interest, discusses the effect of canning upon nutritive values.

We put down a book which we have found exceptionally attractive with the very comfortable feeling that whilst there are many enemies to canned food, the "situation is always well in hand," for there is an army of experts ever studying the enemies and ever on the watch to defeat and exclude them. In these days of war, when more people than before are dependent on canned foods, we are grateful to the authors for a work which shows how little need there is for anxiety about the effects of such foods upon the national health.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

FACTS ABOUT THE RIFLE

SIR,—The editorial footnote on page 316, column 1, gives the frequently quoted reason why wet ammunition results in high shots. It would be interesting to have brief details of the investigations on which the military authorities quoted base their contention. If, as stated, the "jump" is altered by the wetted cartridge driving back on the bolt more forcibly than when partly gripped by the chamber walls, as it is in the dry condition, it seems rather surprising that the alteration in "jump" should always be in the same sense, viz., to give a high shot, no matter what the make, weight or length of the rifle. Have any tests been made to determine whether water in the chamber affects the muzzle velocity?

Further, before dismissing the experienced marksman's contention that the light during rain affects the aim, were tests made from under cover (*i.e.*, under perfectly dry conditions), but firing out into rain, and the tests repeated when the rain had ceased?

D. WEIR.

[In support of our footnote we make the following reply from information given by competent authorities:—

1. So far as is known, no scientific investigation has been carried out with regard to firing in the rain, but the theory that the bullet is "lubricated" by the rain in its passage through the atmosphere may, we think, be safely dismissed because:

(*a*) The bullet would be so hot as to vaporise instantly any raindrop that fell upon it.

(*b*) The bullet leaves the muzzle rotating at a speed of about 2800 revolutions per second, which, we venture to suggest, would throw off any water by centrifugal force if the bullet was not hot enough to deal with it as in (*a*) above.

2. So far as the effect of water—or oil—on the cartridge case is concerned, the proof of the pudding is in the eating, and experiences at Bisley and elsewhere (including the far-flung corners of the Empire) over a period of some twenty years, which we may fairly describe as considerable and extensive, are sufficient to say quite confidently that a wet cartridge is liable to give a high shot, whilst if it is possible to keep the ammunition dry whilst shooting in the rain no alteration in elevation is required in spite of rain, other things being equal.

3. The last remark of the preceding paragraph is qualified by "other things being equal." This brings up the question of the effect of changes of light, which have also been mentioned.

There is a well-known saying amongst riflemen, "light up—sight up," which means that if the target becomes clearer or brighter it may be necessary—depending on the eyesight of the individual—to raise the sights slightly to avoid getting a low shot. The converse is also true and it may well be that the reduction in light caused by a rainstorm or by heavy cloud may sometimes be the cause of a high shot, even before the ammunition has had a chance to get wet.

4. One point on which the writer of the article did not touch is barometric pressure, which, of course, has an effect on the flight of the bullet. This effect is not much noticed with rifles in the ordinary way, although gunners have to include it in their calculations of the "error of the day."

At high altitudes, however, the effect of barometric pressure becomes more apparent. For instance, when shooting near Johannesburg, some 6000ft. above the sea, the elevations required on the sight at long ranges (600–1000 yards) varied very consideraby from those required at Durban or Cape Town.

5. As regards the suggestion in the letter that the "jump" is always altered upwards by wet cartridges, whatever the type of rifle used, there is no evidence that this is so, and in fact it would appear unlikely. Each rifle has its own characteristics; it would appear probable, for instance, that the effect of wet ammunition would in any case be less in a rifle with a front locking bolt (*i.e.*, Ross or Pattern 1914) than in the S.M.L.E.

6. To sum up, the position appears to be as follows:—

(*a*) In wet weather there is the possibility of a high shot occurring from time to time.

(*b*) The explanation suggested for this in the article is not considered to be correct for the reasons given.

(*c*) The possible causes are: (i) water on the cartridge case; (ii) change of light.

(*d*) It should be emphasised that not every shot goes high—there is only the possibility of this occurring.—ED., THE E.]

EARLY BRITISH LOCOMOTIVES

SIR,—Although it is little more than a year since my book "Early British Locomotives" was published (the stock of which has been seriously depleted by enemy action), some interesting pieces of history have turned up, which shed a little more light on the subject. As life is so uncertain in these days, it seems best to put these points on record without delay, in order that they may not be lost.

In the second line of page 11 of my book, speaking of Trevithick's Penydarren locomotive, on further consideration, I should prefer the words "may have been" substituted for "was evidently" (a feed-water heater); and at the top of page 15, the words between "knowledge" and "is" should be omitted.

I am indebted to Mr. E. A. Forward for some corrections and fresh details. He points out that the description of the valve gear of the Blenkinsop engines on page 22 does not correspond with the 1815 drawing. These engines, of course, may not have been all alike. In the one illustrated, reversing was effected by shifting the tappets in their frame, the connection to the valves remaining constant.

Murray's patent for the one-way tappet gear was dated 1801, not 1812.

With regard to the silencing arrangement (pages 25, 26), which I said "appears to be indicated in Fig. 8," it is stated in a letter from Blenkinsop of October 20th, 1813, that the exhaust box was between the cylinders, and Mr. Forward thinks that the tall chimney in the illustration belongs to a factory in the background. This explanation must be accepted as correct.

On the subject of the Wylam engines shown on page 51, he has made the following extremely interesting comment: "Have you ever considered the possibility that the eight-wheeled engines said to have been used at Wylam were really Chapman's double-bogie adhesion engines, wrongly claimed by O. D. Hedley as his father's work?"

This somewhat startling suggestion is not without fairly substantial support. There is the illustration from Gordon's "Elemental Locomotion," reproduced on page 24 of my "Two Essays," clearly labelled "Messrs. W. and E. Chapman, 1812"; and a similar one given by Hebert ("Practical Treatise on Railroads," page 29), called "One of the locomotives of Messrs. Chapman which was employed on the Heaton Colliery" (as a matter of fact, it was the chain engine that was tried at Heaton). There is no mention of Wylam in connection with either of these two, but they are exactly like the two drawings next mentioned.

Wood does not say who was the designer; he calls it: "One of the engines at present used on the Wylam Colliery Rail-road" (first edition, page 154). On pages 144, 145 he says: "Mr. Chapman, in his patent for the application of a chain, described a plan of placing the weight of the engine upon two frames, supported by six or eight wheels; and the Wylam engines, being heavier than the rails would bear, were placed on eight wheels; but the complication of so many wheels, and the unwieldy nature of such a length of framing, formed together so many objections, as to render them almost useless, as a species of moving power."

Nor is Partington more definite. He calls his drawing "A view of a steam carriage employed at Wylam Colliery, Newcastle, for which we are indebted to Mr. Hedley" (second edition, page 177).

Neither Galloway nor Stewart mention the Wylam engines. Evidence in favour of Hedley as the designer is lacking, therefore, in all the early authorities.

O. D. Hedley, writing in 1858, gives all the credit to his father, saying that he took out a patent which was opposed by Chapman, and quotes a letter from Blackett to Hedley which speaks of "the utility of your patent machine" ("Who Invented the Locomotive Engine," pages 30, 33).

Mr. Forward's suggestion should be considered in connection with the remarks in the middle of page 25 and at the foot of page 29 of "Two Essays."

On page 60, lines 4 and 5, read "Kirkintilloch Ry., designed by George Dodds." The same corrections require to be made in the middle of page 62.

Mr. J. F. McEwan has drawn my attention to the fact that the superintendent and engineer of the Monkland and Kirkintilloch Railway in 1831 was George Dodds. The two Killingworth type engines used on that line have hitherto always been put down to Isaac Dodds.

In the Kelvingrove Art Gallery, Glasgow, there is an old engraving of one of them. It has been heavily varnished, and would not reproduce well, but it bears the following inscription, a copy of which has been kindly sent to me by the Deputy Director of the Museum:—

This plan
of the first

LOCOMOTIVE ENGINE MADE IN GLASGOW

is dedicated by permission to

Robert Graham, Esq., of Whitehill, Thomas Graham, Esq., Younger of do., George More Nisbet, esq., of Cairnhill, and others,

DIRECTORS OF THE MONKLAND AND KIRKINTILLOCH RAILWAY

By their most obedient servant,

GEORGE DODDS

Superintendent.

The first of these Engines started upon the Railway, 10th May, 1831.

The principal source of information about these engines is Gordon's "Treatise upon Elemental Locomotion." On page 58 of the second edition (1834) it says:—

> In the beginning of the year 1831 the Directors of the Monkland and Kirkintilloch Railway (near Glasgow) directed their enigneer to make out a plan and specification of two locomotive engines, able to drag sixty tons, gross weight, at the rate of four or five miles an hour. This was done accordingly, and the engines were contracted for by Messrs. Murdoch and Aitken, engineers, Hill Street, Glasgow, who brought the first upon the railway on the 10th day of May, and second upon the 10th of September.

Gordon also quotes at length on the subject from a report of the directors of the M. and K.R. to the proprietors, dated February 1st, 1832, which says that they had "devolved the whole form and plan of these engines to Mr. Dodds, the superintendent." the report is full of praise for "Mr. Dodds," but never mentions his Christian name nor initials. It is therefore obvious that they meant the Mr. Dodds with whose name they and the shareholders were familiar. If they had been referring to another person with the same surname, the Christian name would certainly have been given.

Who George Dodds was I have been unable to ascertain, but the probabilities are that he was one of Isaac's brothers. The most important source of information on the Dodds family (from a quantitative point of view, at all events) is "A Story of Railway Pioneers," by Major S. Snell (1921). Details of the family therein are as follow:—Isaac's father was Thomas D. (died 1805); uncle, Ralph D. (of Killingworth); son, Thomas Weatherburn D. He had also brothers and sisters; one of the latter married John Stephenson (1794–1848), railway contractor (not related to George S.).

George D.'s existence is completely ignored, and Snell, who quotes the report above referred to, has jumped to the conclusion that it referred to Isaac, a mistake in which I followed him, thinking he ought to have known.

Turning to Chapter V, my details of the entries in the old Stephenson ledger were taken from a set of extracts given to me by the late J. G. H. Warren. Mr. Forward has been privileged to examine the original, and has found certain discrepancies and given some omissions.

The date for Nos. 9 and 10 (Seguin's engines) should be March 17th and April 14th, 1828.

With reference to No. 12, the Delaware and Hudson engine, supposed by many writers to have been called "America," a recent discovery of a trunk full of John B. Jervis's letters shows that its name was "Pride of Newcastle."

On page 76 the date December 1st, 1820, is a misprint for 1828. The first footnote should be deleted.

With regard to the Welsh engines, which I have numbered 14 and 15, it now appears that the Tredegar engine stands first in the entry, but no numbers are given. From other entries Mr. Forward infers that they were 14 and 16, the S. and D.R. "Rocket" being 15. For example, there is an entry: "Freight of No. 14 and 16 Travelling engines to Newport"; again, "J. Nicholson's expenses No. 15 Trav. Eng. 25s." As Nicholson was the man usually sent to Darlington to doctor up the S. and D engines, and as it would have cost more than 25s. to send him to Wales, this entry seems to refer to the S. and D. "Rocket."

From the entries relating to the ill-fated Baltimore and Ohio engine, it appears that not only was the tiny "Fraser" loaded with the locomotive, but also with a stationary engine weighing 4 tons or so, which was salvaged and repaired. It seems to have been made for the L. and M. Railway.

On page 81, after "13" at the end of the first line, read "Travelling engine from Carlisle to Liverpool"; delete the reference to "Lancashire Witch"; it was a belated entry relating to the "Twin Sisters."

A correspondent has made the interesting suggestion that what Mr. Glen Taylor and I thought was a packing case for the "Royal William," shown in Fig. 31, was nothing of the kind, but a permanent covering, and is probably quite right.

For the benefit of those interested, I may mention that an article appeared in the *Locomotive* of July, 1940, supplementing the second of my "Two Essays," entitled "British Locomotives in North America."

C. F. DENDY MARSHALL.

Guildford, June 14th.

"COMING CRISIS IN ELECTRICAL POWER TRANSMISSION"

SIR,—The recent article by Mr. H. Rissik upon electric power transmission expresses a number of misconceptions which I think should not go unmentioned. These are to be found principally in the latter part of the article dealing with the so-called "quadrature booster."

The author is, it seems, under the impression that in a transmission line there can exist under certain circumstances, a surplus both of capacitive and inductive kVAR, and that it is possible, by means of some form of transformer or booster, to make the one neutralise the other.

A transmission line possesses both capacity and inductance. The capacitive kVAR which it absorbs depends upon the voltage, while the inductive kVAR depends upon the current in the line. For any given voltage there is a "natural load," at which the capacitive and inductive kVAR are equal and cancel each other.

If the voltage is reduced or the current increased, the inductive kVAR preponderates; if the voltage is increased or the current reduced, the capacitive kVAR predominate. In any case, the compensation of the inductive kVAR by the capacitive kVAR is automatic up to the limit of whichever is present in the smaller amount. If they are equal, as at the "natural load,"

the compensation is perfect and independent of any artificial assistance.

Proposals have been made—among others by Major Taylor—so to regulate the voltage of a transmission line that it would always work at the natural load. This would provide a solution of the compensation problem independently of any additional devices such as boosters. It would, however, introduce so many difficulties into the parallel operation of stations as to be impracticable in most cases.

If, as is nearly always the case, long transmission lines are operated at loads other than the natural load, some form of artificial compensation must be applied. This must take the form of a device which delivers inductive or capacitive kVAR, according to the state of the line. The only devices which will do this are synchronous generators, reactors, and condensers.

A booster or transformer is inherently incapable of such a function, as it will only deliver what is put into it, less its losses. This applies just as much to kVAR where the losses are the magnetising current, as to kW.

With the exception, therefore, of the very small influence of the losses and magnetising current, the electrical conditions at each side of a booster however connected, must be precisely the same. The voltage may be increased or decreased, in either case being balanced by a corresponding decrease or increase of the current; further, the voltage and the current may be advanced or retarded in phase by the same angle, as is the case, for instance, in a star-delta connected transformer. That the phase of both current and voltage must be shifted by an equal amount follows from first principles. If this were not the case, the transformer would be producing inductive or capacitive kVAR as the case might be. If anyone doubts this, he can easily prove it by means of a simple vector diagram.

In a recent article (*Engineering*, May 23rd, 1941, page 402), Mr. Kipps has demonstrated this equal shifting of voltage and current. At the same time, he, in common with Mr. Rissik, seems to think that there is some advantage in such a phase shift, inasmuch as it is alleged to increase the maximum power that may be transmitted without instability.

It is well known that there is an upper limit to the power that may be transmitted stably over a given line, and that the approach to the limit of stability is accompanied by an increase in the "system angle" that separates the voltage vector at one end of the line from that at the other. The increase in this system angle is not, however, the cause of the instability, but merely its symptom. The cause of the instability is the fall of the voltage at the middle of the line (assuming that it is maintained at the two ends).

Any increase of the power transmitted—that is, of the load current—is accompanied by a fall of the voltage on the line. This fall is greatest at the middle and decreases progressively towards the ends. Up to the limit of stability the decrease of voltage is more than compensated by the increase in current, and there is thus a net increase of the power transmitted. The increase of power for a given increase of current becomes, however, progressively smaller as the load increases, until at the static stability limit the power no longer increases as the current increases, because the decrease of the voltage begins to preponderate over the increase in current.

Neutralising the system angle is thus useless. The stability can only be increased by artificially maintaining the voltage at the middle of the line, as, for example, by means of a synchronous condenser, or by looping the line in on to the bus-bars of a generating station.

The compensation of the charging current of the line does not, as Mr. Rissik seems to think, solve the problem of stability. It may increase the limit of static stability, but only by a relatively small amount.

In discussing the relative prospects of A.C. and D.C. transmission, Mr. Rissik tends to exaggerate the difficulties of A.C. working and minimise those of D.C. In fact, the technique of long-distance A.C. transmission is already much more advanced than he apparently is aware. The reasons why large powers are not already being transmitted over distances of the order of 1000 to 2000 miles are less technical than political and economic. What is lacking is not so much electrical as international stability.

C. J. O. GARRARD.

Birmingham, June 11th.

SIR,—I am afraid that I cannot accept Mr. Garrard's criticisms, for it is precisely they which are based on a number of misconceptions regarding synchronous A.C. transmission in general and Major Taylor's system of power transmission in particular.

In the first place, while it is quite true that the problem of reactive power compensation is automatically solved by ensuring that a transmission line always operates at its "natural load," irrespective of the kW load at the receiving end, and that various proposals to this end have been put forward from time to time, this does not get us any further where long-distance transmission is concerned.

A naturally loaded line still produces a vector angular displacement between the synchronous, but otherwise independent voltages at its two ends. This "system angle" amounts to some 10 electrical degrees for every 100 miles of line (at 50 cycles), so that the steady-state stability limit of the transmission system becomes a simple function of the transmission distance. As has been indicated elsewhere by the writer,* in a discussion of Dr. Wall's lucid analysis of the transmission problem,† this limit is equal to the natural load in the case of a quarter-wave line (*circa* 900 miles), for the system angle then attains the critical value of 90 deg. In the case of a half-wave line (*circa* 1800 miles), the system power limit is actually zero, for the system angle is here 180 deg. In other words, no power can be transmitted between the terminals of a half-wave line, since the voltages at its extremities are in anti-phase. These characteristics of long-distance transmission have quite recently been confirmed experimentally by Clarke and Crary in the United States.‡

The point here, of course, is that the stability of a synchronous transmission system is primarily a function of the system angle, and that all voltage and current phenomena on a transmission line are but manifestations of a secondary character. Mr. Garrard's view that the increase in system angle is not fundamental to, but merely symptomatic of instability, and that the real cause of transmission instability is the fall of voltage at the middle of the line, is therefore not only erroneous, but altogether misleading.

Both this fall in voltage and the corresponding increase in current (to which Mr. Garrard refers in his explanation of steady-state instability) are determined by, and are relatively simple functions of, the increase in system angle. This is, after all, only to be expected, for what we somewhat loosely call "power transmission" is really the interchange of power between synchronous machines. Such power interchange can only take place by virtue of a physical angle of displacement between the machine rotors which manifests itself as an electrical angle of displacement between the air gap voltages of the machines—the so-called "system angle." This fundamentally physical or electro-mechanical phenomenon lies at the very heart of synchronous A.C. transmission, and all modern stability theory is founded upon it.

Neutralising the system angle is therefore not useless, as Mr. Garrard maintains, but of supreme importance to the future development of long-distance transmission. Taylor's quadrature booster or reactance compensating transformer fulfils just this function, but under conditions of natural load operation, *i.e.*, of variable voltage transmission. The amount of voltage variation required is, however, not very great, since the majority of long-distance transmission systems operate, for purely economic reasons, in the vicinity of the natural load.§

To avoid the necessity for natural load working characteristic of the Taylor system of transmission (for a transformer is, of course, incapable of adding to or subtracting from the net reactive power absorbed by a transmission line, a fact which Mr. Garrard rightly emphasises), resort must be had to synchronous machines, an arrangement leading to Baum's system of reactive power compensation. In the Baum system, employing intermediate synchronous condenser stations on a long transmission line, the "system angle" is not so much neutralised as broken up into fragments. The transmission system as a whole is subdivided into a number of series-connected sections in each of which the system angle is but a fraction of the total system angle. As the result, the stability of the system as a whole is governed by the power-angle characteristics of its individual sections, which being of much shorter length are inherently more stable. For various reasons, however, the Baum system (first put forward in 1921) no longer merits serious consideration as a practicable solution of the long-distance transmission problem.

While I agree with Mr. Garrard that the reasons why distances of 1000–2000 miles have not yet been covered are politico-economic rather than technical, I cannot help feeling that he is unduly optimistic about the degree of technical advance that has been made in the sphere of long-distance A.C. power transmission. For reasons which I have already indicated, and which are amply confirmed by Clarke and Crary in their recent paper on this subject, even American engineers would hesitate to-day before putting down a super-power transmission system exceeding 400–600 miles in length.

H. RISSIK.

London, S.W.6, June 14th.

* *Electrician*, May 24th, 1940, page 379.

† *Ibid.*, February 16th, 1940, page 119.

‡ Edith Clarke and S. B. Crary, "Stability Limitations of Long-distance A.C. Power Transmission Systems" (a paper read at the Midwinter Convention of the Amer. I.E.E. in January, 1941).

§ See Table I of Reference (‡).

Standard Single-Storey Factories

WARTIME Building Bulletin No. 15, "Standard Designs for Single-storey Factories for War Industries, with Notes on Siting and Lay-out," H.M. Stationery Office, price 1s., issued by the Building Research Station of the Department of Scientific and Industrial Research, brings up to date and extends the information given in earlier Bulletins on the design of wartime factories. The modification of earlier designs are put forward mainly as a result of experience of air raids. The Bulletin is divided into two parts. Part I is a review of standard factory types and has been written in consultation with the Ministry of Works and Buildings, Ministry of Home Security, Iron and Steel Control and representatives of the constructional steel work industry. The revised designs should be highly resistant to demolition by bombing. They are intended for use, during the war, without roof glazing, but provision is made for the addition of glazing after the war, or during the war if need be. Two new types are introduced. One uses a range of rolled steel sections which may assist towards a better distribution of the demand on steel mills, and the other is a design developed by the Ministry of Aircraft Production. Two types provide protection against incendiary attack and these are to be preferred wherever the occupancy of the building involves an appreciable fire hazard. A general discussion in Part II on how to conceal factories by camouflage, and how to make them less vulnerable, shows that these problems are complementary. Some of the information on camouflage has been published before, but it has not previously been shown how siting and arrangement can make factories less vulnerable. A solid block of regularly shaped and arranged buildings is very vulnerable and difficult to conceal, and a hollow plan is only slightly better. The best lay-out is one where the buildings are arranged along a curved line. Random distribution of groups of factories making the same products does not necessarily secure the greatest protection, and sometimes it is better that interconnection between production lines for one type of product should be possible. This "lattice principle" can be combined with camouflage and several examples are given in the Bulletin for factories of 10,000–80,000 square feet. On application to the Building Research Station, an analysis of the vulnerability of any vital project can be arranged.

Wartime Building Industry

IN a statement made on Wednesday, June 11th, explaining the reasons for the application of the Building and Civil Engineering Industries Order, Lord Reith, Minister of Works, said that the Order marked another stage in the drive for increased output. The Ministry had, he said, further plans for the better co-ordination and direction of the building industry for maximum war effort, in order to ensure that the industry's experience, staff, plant and so forth were used to best effect. Another step was the elimination of any work not part of the war effort. The task allotted to the industry was greater than could be carried in the ordinary way by the men available. That meant that the output of the industry and everyone in it must be greater than ever before. In the next six months, and in spite of all handicaps, records must be broken. Before the war the strength of the building industry, Lord Reith said, was about 1,350,000. To-day it was about 750,000. Many of the strongest workers being of military age were in the Services, so there was a decrease in output per man-hour, while there had been wastage through other causes, normal and otherwise. Included in the building national programme were ordnance and munition and other war factories, aerodromes, defence works, emergency hospitals, hostels, along with repairs to factories and houses and essential services. This work was all-important and all-urgent. Much of this work had to be done in lonely parts and the men who created a complete town of factory, hostels, canteens, and so forth where before there was only waste land never saw that town filled with men and women producing the needed weapons of war. The country, Lord Reith concluded, had reason to be grateful to the building and engineering industries, but it asked for more still.

The Design of Condensing Plant and Cooling Water Systems*

By W. T. BOTTOMLEY, A.R.T.C., Assoc. Member

Introduction

In the generation of electric power by steam turbines, considerable attention has been given to the improvement in economy to be effected by increasing the initial steam temperature and pressure and by adopting progressive feed heating and interstage reheating. The purpose of all these devices is to raise the mean temperature at which heat is added to the working medium which is the mean temperature at the upper limit of the thermal cycle. Little attention has, however, been given recently to the economy to be effected at the lower temperature limit of the cycle, which is the average temperature at which the heat is extracted from the working medium in the condenser. The only important paper within the last decade or two on the subject of condenser design is that given by Guy and Winstanley in 1934.[1] The reason for the neglect of this subject may be due to the idea that there is little more to be said. Except for the substitution of the steam ejector for the reciprocating air pump and the better design of the steam passage through the condenser to reduce the pressure drop and recover the velocity head, it would appear that the condensers of to-day show little improvement on the condensers of twenty years ago. Indeed, it might be said that the same rule is adopted now for determining the size of condenser and quantity of circulating water as was adopted twenty or twenty-five years ago, namely, 6 lb. or 7 lb. of steam condensed per square foot of condenser surface per hour at economical load with circulating water seventy to eighty times the quantity of steam condensed. These rules are for land practice. For marine practice the rule for the quantity of water is apparently the the same, but the steam condensed per square foot of surface is considerably greater and depends on the type of ship. The firm with which the author is associated has made a practice for a number of years of specifying 6 lb. of steam per square foot, although manufacturers would consider 7 lb. to 7½ lb. per square foot satisfactory ; yet, in spite of this, general requests have been received from operating engineers, both in this country and abroad, for larger condensers. On the other hand, we have to consider the desire of authorities to keep down the initial cost to the minimum consistent with economy. This point was emphasised by Mr. Johnstone Wright, Chief Engineer to the Central Electricity Board, in his Presidential Address at the Institution of Electrical Engineers[2] recently.

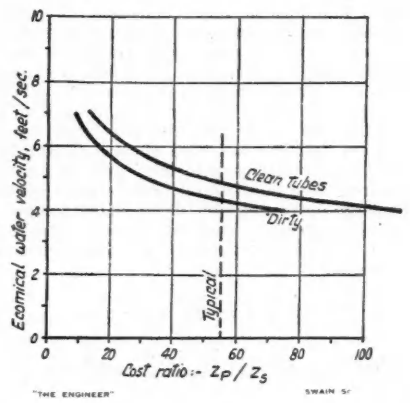


FIG. 1—*Economical Water Velocity Through the Condenser Tubes*

The relation between the normal vacuum in the condenser and the average temperature of the inlet circulating water has been more or less fixed by convention. Thus, 29in. vacuum in the condenser is specified when the average inlet circulating water temperature is 55 deg. Fah., and in special cases the same vacuum is specified when the water temperature is 60 deg. Fah.

The performance for cooling towers of the wooden type were also specified on conventional lines. The normal recooled water was specified at 77 deg. to 80 deg. Fah., for which a normal vacuum in the condenser of 28in. was expected. Due to the improved efficiency of the hyperbolic concrete tower, however, there appears to have been a tendency to depart from the usual convention and to base the specified normal performance on economical grounds ascertained by trial-and-error methods. Mr. Lawton states in his paper on Hams Hall[3] : "It will be found that the condenser design and the cooling tower size are so fundamentally related that it is impossible to decide on one without reference to the other." The author understands that for Hams Hall about fifty different schemes were considered before a decision was made.

In the United States of America the size of condenser is not out of the ordinary, but the quantity of water sometimes exceeds anything we have in this country. Port Washington power station (U.S.A.) is the most efficient power station in the world, and monthly and yearly average operating figures have been published from time to time. The following figures for 1937 have been taken from *Combustion*, February, 1938, the average load being nearly steady at 53,000 kW and generated by one machine :—

1937	Average for March.	Average for August.	Yearly average.
	Deg. F.	Deg. F.	Deg. F.
Condensate temperature	45·5	74·4	57·5
Circulating water inlet	34·1	63·6	45·7
Difference	11·4	10·8	11·8
Temperature rise of water	4·2	4·0	4·1
Final temperature difference	7·2	6·8	7·7
Remarks	Coldest monthly average inlet temperature	Hottest monthly average inlet temperature	

The temperature rise of the circulating water of 4 deg. Fah. shows that the quantity of circulating water is nearly 250 times the quantity of steam condensed.

After the care taken in improving the upper temperature limit of the thermal cycle, it is only logical to expect that the same consideration should be given to the economy which can be effected at the lower end of the cycle, particularly in view of the conflicting demands. Whatever may have been the justification for the conventions adopted in the past, the conditions have altered since then, the most important of which is perhaps the average loading of the plant, which, especially in base load power stations, is considerably higher now than it was before. The cost of fuel per kilowatt-hour generated has not, however, materially altered. The fuel consumption per unit has been reduced to half during the last thirty years, but this has been offset by the rise in the price of coal, which has doubled itself in the same period.

Conditions Determining the Condensing Temperature in Practice

The theoretical lower temperature limit of the thermal cycle is the temperature of the water in the river for river water cooling ; for cooling tower schemes, it is the atmospheric wet bulb temperature. On the average throughout the year these two temperatures are about the same in a given locality, *i.e.*, about 52 deg. Fah. in this country. Needless to say, the approach of the condensing temperature to the theoretical temperature is limited by the question of cost, and the aim should be to design the plant so that the total annual cost, including capital charges, is a minimum.

Owing to the number of variables involved, one would expect that a general solution of the conditions for minimum cost would be difficult, but by treating the subject mathematically it can be proved that for conditions of minimum cost, the size of the condenser, the size of the tower, and the quantity of circulating water are each determined independently of the other two, which simplifies the problem considerably.

It is proposed to give the general mathematical treatment of the subject and to discuss the results in Section I following, and to discuss the condenser constants in Section II and the cooling tower constants in Section III.

SECTION I

The General Economic Theory

The cost of power plant in general as affected by the design of the condensing plant, the circulating water system, and cooling towers, if cooling towers are used, is directly dependent on five variables. These are the condenser surface S, the quantity of circulating water G, a dimension depending on the size of the tower F (if towers are used), the power absorbed by the circulating water pumps P, and the vacuum temperature at the top of the condenser T.

This is expressed mathematically as follows :—

Cost = C = f (S, G, F, P, T,), where f represents any function.

The condition to be satisfied for minimum cost is obtained by differentiating and equating to zero

$$d\,C=\frac{\delta C}{\delta S}d\,S+\frac{\delta C}{\delta G}d\,G+\frac{\delta C}{\delta F}d\,F+\frac{\delta C}{\delta P}d\,P+\frac{\delta C}{\delta T}d\,T$$
$$=Z_S d\,S+Z_G+Z_F d\,F+Z_P d\,P+Z_T d\,T$$
$$=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where Z_S, Z_G, &c., represent the increase in cost per unit increase in the variable with which each is connected, *i.e.*, S, G, &c., assuming that the other four variables are constant. When Eq. (1) is applied to a given set of conditions and represents average annual conditions, there will be only three independent variables S, G, and F. The variables P and T, representing the power for pumping and the vacuum temperature, are not independent, but depend on the other three ; that is to say,

$$d\,P=\frac{\delta P}{\delta S}d\,S+\frac{\delta P}{\delta G}d\,G+\frac{\delta P}{\delta F}d\,F$$

and

$$d\,T=\frac{\delta T}{\delta S}d\,S+\frac{\delta T}{\delta G}d\,G+\frac{\delta T}{\delta F}d\,F.$$

Substituting these differentials in Eq. (1) and rearranging the terms, the condition for minimum cost is given by

$$d\,C=\left\{Z_S+Z_P\frac{\delta P}{\delta S}+Z_T\frac{\delta T}{\delta S}\right\}d\,S$$
$$+\left\{Z_G+Z_P\frac{\delta P}{\delta G}+Z_T\frac{\delta T}{\delta G}\right\}d\,G$$
$$+\left\{Z_F+Z_P\frac{\delta P}{\delta F}+Z_T\frac{\delta T}{\delta F}\right\}d\,F$$
$$=0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

But $d\,S$, $d\,G$, and $d\,F$ represent any arbitrary change, and are not nil. Therefore the expressions in each bracket must be nil independently ; that is to say,

$$Z_S+Z_P\frac{\delta P}{\delta S}+Z_T\frac{\delta T}{\delta S}=0 \quad . \quad . \quad . \quad . \quad (3A)$$

$$Z_G+Z_P\frac{\delta P}{\delta G}+Z_T\frac{\delta T}{\delta G}=0 \quad . \quad . \quad . \quad . \quad (3B)$$

$$Z_F+Z_P\frac{\delta P}{\delta F}+Z_T\frac{\delta T}{\delta F}=0 \quad . \quad . \quad . \quad . \quad (3C)$$

Eqs. (3A) and (3B) apply to river water cooling, and all three equations apply to cooling tower schemes.

It is shown in Sections II and III that for constant water velocities

$$\frac{\delta T}{\delta S}=-\frac{W}{S^2}\frac{R}{m} \quad . \quad . \quad . \quad . \quad \text{see Eq. (14)}$$

$$\frac{\delta T}{\delta G}=-\frac{W}{0{\cdot}6\,G^2}\left(\frac{m-a}{m}\right) \quad . \quad \text{see Eq. (15)}$$

$$\frac{\delta T}{\delta F}=-\frac{1}{1{\cdot}1}\frac{W}{F^2} \quad . \quad . \quad . \quad . \quad \text{see Eq. (28)}$$

where W represents the load on the condenser and R the overall thermal resistance, and it will be noticed that the value of each differential in one variable is independent of the other two variables.

It is also shown in Sections II and III that $\frac{\delta P}{\delta S}$ is constant for a fixed water velocity in the tubes, and that $\delta P/\delta F$ is nil. The value of $\frac{\delta P}{\delta G}$ for economical velocity in the circulating water pipes can be treated as constant within the range of water quantities considered.

Therefore the solutions of Eqs. (3) are given by

$$\frac{W}{S}=\sqrt{\frac{Z'_S}{Z'_T}\frac{m}{R}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4A)$$

also

$$x=\frac{W}{0{\cdot}6\,G}=\sqrt{\frac{Z'_G}{Z'_T}\frac{m}{0{\cdot}6\,(m-a)}} \quad . \quad . \quad (4B)$$

and

$$\frac{W}{F}=\sqrt{\frac{Z_F}{Z'_T}\times 1{\cdot}1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4C)$$

where

$$Z'_S=Z_S+Z_P\frac{\delta P}{\delta S}$$
$$Z'_T=Z_T/W$$

and

$$Z'_G=Z_G+Z_P\,\delta\,P/\delta\,G.$$

It will be noticed from Eqs. (4) that the value of each variable for conditions of minimum cost is determined independently of the other two variables.

The above conditions for minimum cost are given in terms of fixed water velocities. The water velocities should, however, be the economical velocities. The economical water velocity in the condenser tubes is given by Eq. (22) in Section II[4], and the determination of the economical velocity in the circulating water pipes presents no difficulty.

Economical Water Velocity in the Tubes

The economical velocity of the water in the condenser tubes is shown in Fig. 1 in terms of a cost ratio, the ratio being the capitalised value of the cost of power for pumping per kilowatt to the capital cost of extra condenser surface per square foot. Two curves are given, one for clean tubes and the other for average dirty conditions. A dotted line shows a typical case. It will be seen that the economical velocity is less than 5ft. per second. The author has been informed on several occasions by condenser manufacturers that the economical velocity is about 7ft. per second, and in the United States a velocity of 7ft. or 8ft. per second is considered the most economical. As this is considerably higher than the velocity indicated by the curve, the author hopes that some explanation for the discrepancy will be produced in the discussion. It has been suggested that the higher velocity will keep the tubes cleaner. While this may be true, it is difficult to prove it. Care, however, should be taken in designing the waterboxes when using low velocities, so that the water

* North-East Coast Institution of Engineers and Shipbuilders, March 28th, 1941.

[1] "Some Factors in the Design of Surface Condensing Plant," by Dr. H. L. Guy and E. V. Winstanley, I. Mech. E., 1934.

[2] Inaugural Address, October, 1939, I.E.E., Vol. 86, page 14.

[3] "Design and Operation of Hams Hall Power Station," by F. W. Lawton, I.E.E., Vol. 85, 1939, page 487.

[4] See Appendix for an alternative method of obtaining the economical water velocity in the condenser tubes.

should be distributed as evenly as possible in the different tubes and that there should be no reversal of flow.

Economical Condenser Surface

The condition for economical condenser surface is shown in Fig. 2, and is given in the form of 1000 B.Th.U. per square foot of internal surface of the tubes per hour, or approximately the pounds of steam condensed per square foot of surface per hour, against a cost ratio Z'_S/Z'_T, where Z'_S represents the cost of extra condenser surface per square foot (internal tube surface), including the capitalised

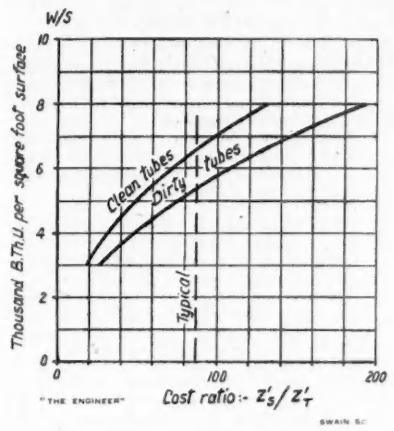


FIG. 2—*Economical Load on Condenser*

value of the cost of pumping against the head across the condenser, and Z'_T represents the capitalised value of the annual loss due to raising the vacuum temperature 1 deg. Fah. per 1000 B.Th.U. extracted per hour. The cost of pumping depends on the velocity through the tubes, but is independent of the total quantity of circulating water. Two curves are given, one for clean tubes and the other for average dirty tubes. A dotted line is shown representing a typical condition met in practice in this country, and it will be seen that the loading of the condenser should be about 5 lb. of steam per hour per square foot of surface under normally dirty conditions, assuming a water velocity of 5ft. per second through the tubes.

The formula for the curve in Fig. 2 is given in Eq. (4A). It would appear from Fig. 2 that a liberal design of condenser is justified.

Quantity of Circulating Water

The quantity of circulating water depends on the length of the circulating water system and the amount of static lift. The condition for minimum cost is represented in Fig. 3, where the quantity of circulating water is indicated by the temperature rise through the condenser. The results are plotted against a cost ratio Z'_G/Z'_T, where Z'_G represents the cost of the circulating water system per extra gallon per

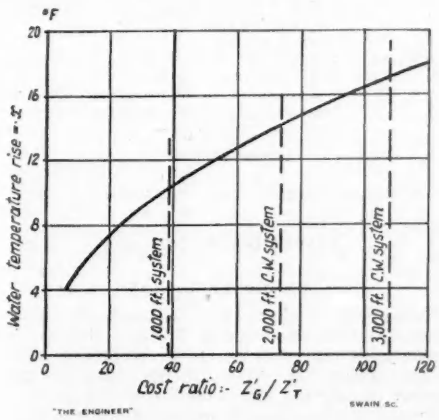


FIG. 3—*Economical Quantity of Circulating Water*

minute of water, including the capitalised value of the cost of pumping through the system (apart from the condenser) and including the cost of pumping against the static lift. The latter item is important when towers are used. Dotted lines are shown in the figure showing typical cost ratios for river water cooling for circulating water systems of 3000ft., 2000ft., and 1000ft. in length, excluding the loss of siphon head. The dotted line for 2000ft. also represents the condition for a cooling tower scheme having a static lift of 30ft. in conjunction with a circulating water system of 1000ft. The economical cooling range for the tower in this instance is 14 deg. Fah., and it will be noted that the cooling range for the tower is not dependent on the size of the tower. Fig. 3 shows for river water schemes that the longer the circulating water system the less should be the quantity of water used, which is what one would naturally expect. Since the temperature rise of the water is higher for longer systems, the normal specified vacuum should be lower, but the increase in the vacuum temperature is not equal to the increase in the water temperature rise, but is only 61·5 per cent. of it, in accordance with Eq. (13) given later.

Size of Cooling Towers

Some difficulty has been experienced in finding a basis for determining the economic size of cooling towers and the corresponding value of the cooled water temperature, partly because the various corrections received are inconsistent and partly because there does not appear to be a generally accepted theory for the performance of towers. The author has not so far found this subject dealt with in any British journals or transactions. Some papers have been given by Mr. Gueritte,[5] but they do not produce a theory which is required for the present purpose.

Several papers have been published in the United States,[6] but the author has found that the theory

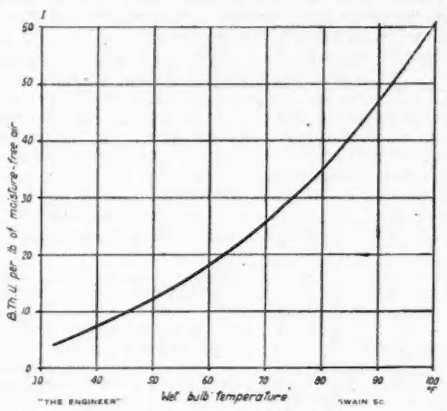


FIG. 4—*Heat Content of Mixture of Air and Water Vapour in B.Th.U. per lb. of Moisture-free Air (Neglecting Sensible Heat of the Liquid)*

developed by Merkel[7] in Germany is the most rational and agrees closely in form with test results.

Merkel showed that the transference of heat from wetted surfaces to the surrounding air per square foot of wetted surface is proportional to the difference between the heat content of saturated air at the temperature of the wetted surface, per pound of moisture-free air, and the heat content of the cooling air. The heat content of air is shown in Fig. 4 for different wet-bulb temperatures. The transfer of heat is also proportional to the coefficient of heat transfer for dry air which depends on the air velocity. From this a performance coefficient is obtained for the overall cooling in a tower which is connected with

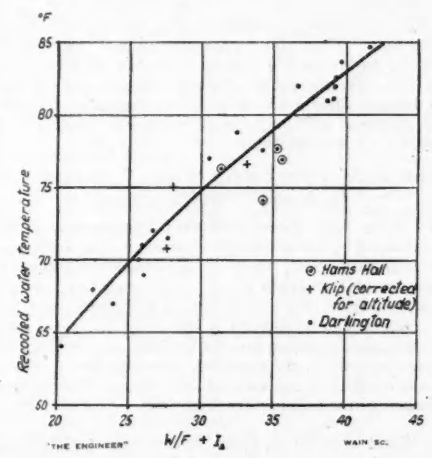


FIG. 5—*Cooling Towers. General Curve giving the Performance for any Range of Cooling to 20 deg. Fah. and for any Wet Bulb Temperature from 33 deg. to 65 deg. Fah.*

the rainfall at the base of the tower by a straight-line relation, the two constants for which are determined from the results of tests. The rainfall is defined as the feet of water falling on the base area of the tower per hour, and is measured by the number of gallons per minute per square foot of base area.

The author's interpretation of Merkel's theory is explained in Section III, and a single curve is deduced and shown in Fig. 5, which appears to agree very well with the performances of towers of the hyperbolic type over the range of sizes found in practice. The constant for the curve was found from a special test carried out on the tower at Darlington power station, particulars of which are given later, and the results agree very well with a number of further tests at Darlington over long periods covering a range of wet bulb temperatures from 33 deg. to 64 deg. Fah., and also agrees with published performances of the towers at Hams Hall[8] at Birmingham and Klip in South Africa.[9]

From this curve the conditions for minimum cost have been found, and results are given in Fig. 6, which shows the loading per square foot of base

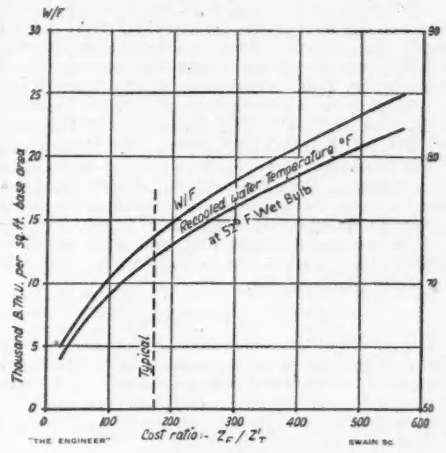


FIG. 6—*Economical Cooling Tower Size*

area plotted against a cost ratio Z_F/Z'_T, where Z_F is the cost of the tower per square foot of base area. The curve also shows the corresponding recooled water temperatures for an average wet bulb temperature of 52 deg. Fah. The position marked by the dotted line represents a typical cost ratio obtained in practice in a base load station, indicating that it is reasonable to expect an average re-cooled temperatube of 72 deg. Fah. when the wet bulb is 52 deg. Fah., the ratio W/F being 14. This, in conjunction with 14 deg. Fah. cooling range already suggested, indicates that the economical rainfall at the tower base should be 100 gallons per hour per square foot.

Effect of the Circulating Water System on the Economic Ratio of the Quantity of Water to Condenser Surface and on the Number of Passes and the Length of Tubes

It is apparent from Figs. 2 and 3 that although the length of the circulating water system does not affect the economic surface area of the condenser, it does affect the economic ratio of the water quantity to condenser surface, and therefore affects the number of passes and the length of tubes.

From the equations for Figs. 2 and 3 it will be found that the economic ratio of water to surface is independent of the vacuum temperature. The ratio is shown in Fig. 7 plotted against the cost ratio Z'_G/Z'_S, both costs including the cost of pumping. Two curves are given, one for clean tubes and the other for normally dirty tubes. Dotted lines show typical conditions for circulating water system lengths of 3000ft., 2000ft., and 1000ft., corresponding to those shown in Fig. 3. The formula for the curves in Fig. 7 is

$$G/S=\sqrt{Z'_S/Z'_G\times(m-a)/0\cdot6\,R} \quad . \quad (4D)$$

The economic ratio of the water to condenser surface, in conjunction with a fixed water velocity through the tubes, determines the number of passes and the length of tubes. The relation is given by the following equation :—

$$\frac{p\,l}{d}=7\cdot8\,v\frac{S}{G}=4\cdot68\frac{v\,x}{W/S} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

For a tidal circulating water system of over 2000ft., or for cooling towers, the economic ratio of G/S is about 0·6, and if the velocity is taken at 5ft. per second, the economic value of $p\,l/d$ is 65.

As the tidal river is usually dirty and some cooling towers use sewage effluent, it is preferable to use 1in. O.D. tubes No. 18 S.W.G., for which $d=0\cdot902$in. For any but the largest machines, this condition requires a four-pass condenser with a length of tube of nearly 15ft. With three passes the tube length is nearly 20ft., and is too long for machines of less than 20,000 kW. With two passes the length of tube would be nearly 30ft., which is out of the question for various reasons.

Since most power stations in this country use tidal river water or cooling towers, this condition, which requires a four-pass condenser, arises frequently. But the usual standard condensers supplied by manufacturers are either two or three-pass condensers, and the author understands that to convert standard condensers to four-pass would increase the cost per

[5] "Recent Developments in the Design and Working of Cooling Towers," Soc. Ing. Civils de France, British Section, by T. J. Gueritte, 1927; "Modern Tendencies in Cooling Tower Design," same author, E.P.E.A. Technical Group, 1937.

[6] Coffey and Horne, "A Theory of Cooling Towers Compared with Results in Practice," A.S.M.E. *Journal*, 1914, 1915, 1916, 1920; Lewis, "Evaporation of a Liquid into a Gas," *Mech. Eng.*, Vol. 44, 1922; Robinson, "The Design of Cooling Towers," *Mech. Eng.*, Vol. 45, 1923.

[7] *Z.V.D.I.*, Vol. 70, 1926, page 123.

[8] *Loc. cit.*

[9] "Klip Generating Station," by V. Pickles and J. S. Trelease, Trans., S.A.I.E.E., May, 1940.

square foot. The other alternative, assuming 1in. tubes are necessary, is to increase the quantity of water beyond the economic limit, but this would also add to the cost. The author suggests that this difficulty should not arise, and that the generally accepted standard design of condenser should, if possible, be made more suitable for the usual conditions met with in practice. The author is not aware that there is any difficulty with four-pass condensers in operation. The condensers at Carville "B" power station have four passes and are considered satisfactory.

At the other end of the range there is the condition for the single-pass condensers for large machines. This condition is justified when the power station is placed on the river front of a non-tidal river, and the length of the circulating water system is short enough to justify an economical water temperature rise of under 6 deg. Fah. Particulars of tests carried out on a single-pass condenser are given in a paper by G. H. Van Hengel.[10] The tubes were of 1in. O.D. and 23ft. 9in. between tube plates. The performance of this condenser, however, does not appear to be so good as that at Port Washington, because the difference between the condensate temperature and the circulating water outlet temperature is about 12 deg. Fah., as compared with 7 deg. Fah. at Port Washington. Also, it is not able to take full advantage of low water temperatures.

Typical Cost Ratios

The results of the above investigation are given in terms of cost ratios with almost mathematical precision, as deduced from design constants, and although in the figures the position of typical cost ratios are indicated, they are only suggestions for guidance and do not affect the main argument.

It is proposed here to explain the basis of the typical cost constants from which the cost ratios were derived. The prices are all pre-war prices, but the rise in prices now should not materially affect the ratios.

The Cost per Square Foot of Condenser Surface (Z_S)

This is usually given as 10s. to 12s. per square foot, and includes the effect of increasing the surface on the outer casing and end doors, tube plates, &c. But the size of the condenser affects the size of the turbine house; the larger the diameter, the higher must be the turbine floor level, and longer tubes require greater withdrawal space. If the turbines are placed transversely in the building the spacing of the machines is affected by the length of tubes, while if the turbines are placed longitudinally, the width of the building must be sufficient to allow for the tube withdrawal. Whichever lay-out is adopted, two of the building overall dimensions are affected by the condenser surface, *i.e.*, the height and either the width or the length. These, in conjunction with the third dimension, give the extra cubic feet of building space per square foot of condenser surface. The extra volume of building space and the cost will depend on the size of the plant, and the author assumed 6s. per square foot of condenser surface for the effect on the building and 12s. per square foot for the increase in the cost of the condenser, making 18s. total for Z_S.

The Cost of Pumping Power per Kilowatt (Z_P)

This will depend on individual conditions and average loading. It was assumed that the pumps, including standby, would be running at full power for 50 per cent. of its life, *i.e.*, 4380 hours per annum on the average, or 4380 kWh per kilowatt per annum. It is debatable whether the cost per unit should be only the cost of fuel or should include the total cost of generation in bulk. The latter has been assumed, taking 0·22d. per unit, giving £4 per kilowatt per annum. Capitalised at 10 per cent., gives £40, which is brought up to £50 per kilowatt to include the cost of the pump and motor.

The Cost per Square Foot of Condenser Surface, including Cost of Pumping Across the Water Space (Z'_S)

The kilowatt for pumping across the condenser is $\left(\frac{v}{36}\right)^3$ per square foot of condenser surface—see Eq. (21). At 5ft. per second and £50 or 1000s. per kilowatt, the cost of pumping is 2s. 8d. per square foot of condenser surface, which, added to 18s. for Z_S, gives 20s. 8d. per square foot for Z'_S. However, a round figure of 20s. was assumed in Fig. 2.

The Cost per Gallon per Minute of the Circulating Water System, including the Cost of Pumping (Z'_G)

The cost of the pipe work was worked out from prices of different sizes of pipes over a large range, assuming different velocities. The cost per 1000ft. length, including pumping at constant velocity plotted against the gallons per minute, gives approximately a straight line not passing through zero. The slope of the line gives a rate of 8s. per 1000ft. per gallon per minute at the economical velocity, which was found to be about 6ft. per second. Of this, 1·6s. is due to the cost of pumping. To this must be added the cost of at least four valves, which amount to a total of about 1s. per gallon per minute.

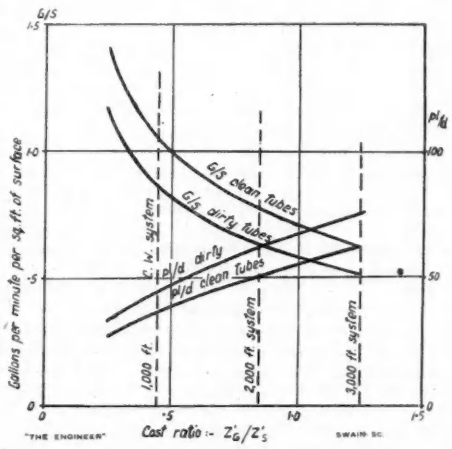
The cost of pumping against a static lift due to loss of siphon, or due to the lift to the hot water trough of the cooling tower at £50 or 1000s. per kilowatt, amounts to 3s. per 10ft. lift per gallon per minute. The cost of a 30ft. lift to the cooling tower is therefore about the same as the cost of 1000ft. of circulating water system on the level, including the cost of pumping.

The Cost of Cooling Towers (Z_T)

The pre-war cost of towers appears to be about 32s. to 42s. per extra square foot of base area, depending on the size of the tower. The higher cost rate applies to the large towers.

The Value of 1 deg. Fah. of Vacuum Temperature (Z_T and Z'_T)

The value of 1 deg. Fah. of vacuum temperature depends on the normal vacuum. The extra kilowatt output due to improvement in vacuum should offset the extra kilowatts for pumping, and should be valued at the cost of power, *i.e.*, £40 per extra kilowatt. It is assumed that the turbine exhaust area will, if possible, be increased with the improved normal vacuum, and *vice versa*, in order to keep the percentage, leaving losses constant. To allow for this, the cost per kilowatt due to varying the vacuum temperature was reduced to £30. It is assumed that, at constant leaving loss, the extra kilowatts obtained for 1 deg. improvement in vacuum temperature is 0·25 per cent. of the kilowatt output of the machine



Curves for pl/d are based on water velocity 5ft. per second.

FIG. 7—*Economical Condenser Design Ratios*

at economical load; therefore the value of Z_T is 1s. 6d. per kilowatt output of the machine at economical load. Z'_T is the corresponding cost per unit W, and the value of Z'_T assumed for the figures is for W = 6·5 per kilowatt, which represents an efficient machine of 30,000 kW C.M.R., 3000 r.p.m., supplied with steam at 600 lb. gauge, 800 deg. Fah., and having progressive feed heating.

The Effect of Departure of the Variables from Positions of Minimum Cost

It must have been noticed by anyone who has ascertained by trial-and-error methods the conditions for minimum cost, that considerable departure of the variables, surface area, water quantity, or size of tower, from the conditions of minimum cost can be made without materially affecting the total cost. The mathematical explanation of this can be obtained from the analysis given above. In each case the total cost as affected by one of the above variables is expressed in the following form:—

Total cost $= a\,z + \frac{b}{z}$, where z is the variable and a and b are constants.

Let $z = q\,zo$, where zo is the value of z for minimum cost. The value of zo is $\sqrt{b/a}$. Therefore, in general, the total cost $= \sqrt{a}\,\sqrt{b}\left(q + \frac{1}{q}\right)$, and the ratio of cost for any value of q to the minimum cost when $q = 1$ is $(q^2+1)/2\,q$.

The following table shows the relative total costs as affected by the variable, for different values of q:

q.	Percentage increase above minimum cost.
1·3	+3·45
1·2	+1·67
1·1	+0·45
1·0	0
0·9	+0·55
0·8	+2·5
0·7	+6·4

It will be seen that the variable and therefore the capital expenditure can be reduced 20 per cent. below the value for minimum cost without increasing the total cost as affected by the variable by more than 2·5 per cent. But if a reduction of 20 per cent. is made on all three variables, the total fuel consumption will be increased by over 2 per cent. on the average, and the effect will be magnified under extreme conditions of load and dirtiness of the condenser. There will therefore be more difficulty in obtaining the output under extreme conditions. At the same time, while the limitation due to economy in initial cost is always present, there is a tendency to forget, after the plant has been in operation for some time, that the plant was originally designed for economy in initial outlay. It is therefore recommended that the plant should always be designed for conditions of overall minimum cost, if possible.

APPENDIX

List of Symbols

A = Difference between vacuum temperature at top of condenser and the temperature of circulating water inlet to condenser in degrees Fahrenheit.
B = Difference between vacuum temperature at top of condenser and the temperature of circulating water outlet from condenser in degrees Fahrenheit.
C = Cost in general.
F = Rainfall area at base of cooling tower in square feet.
G = Quantity of circulating water in gallons per minute.
I = Heat content of mixture air and vapour at atmospheric wet bulb temperature in B.Th.U. per lb. of moisture-free air.
I_A = Heat content of air entering tower.
K = Coefficient of heat transfer B.Th.U./square foot per hour per degree Fahrenheit temperature difference.
L = Latent heat of moisture in air.
P = Power for circulating water pumps in kilowatts.
R = Overall thermal resistance from steam to water across condenser tubes × 1000 = 1000/K.
R° = Portion of overall thermal resistance which is independent of the water velocity.
R_1 and R_2 = Thermal resistance constants based on Eagle and Ferguson's experiments.
R′ = Thermal resistance from tube to water inside × 1000.
S = Total internal tube surface of condenser in square feet.
T = Temperature corresponding to the vacuum in the steam space at the top of the condenser in degrees Fahrenheit.
W = Load on condenser in 1000 B.Th.U. per hour.
Z_S, Z_G, &c. = Cost per unit of variable, as defined in Eq. (1).
Z'_S, Z'_G = Cost per unit of variable, as defined in Eq. (1), including cost of pumping.
$Z'_T = Z_T/W$.
a = Constant in Eq. (12) = 0·4.
d = Internal diameter of condenser tube in inches.
d = Represents differential operator.
e = Evaporation constant.
f = Represents a function in general.
l = Length of condenser tube between tube plates in feet.
m = Constant in Eq. (12) = 1·04.
p = Number of passes in condenser.
t = Temperature of water inlet to the condenser in degrees Fahrenheit.
v = Velocity of water in the condenser tubes in feet per second.
x = Temperature rise of circulating water through condenser = cooling range of cooling tower.
y = Vacuum temperature fall or rise between the top and bottom of the condenser.
z = General variable.
α, α_o, α_1, α_m = Cooling tower constants in Eq. (24).
δ = Partial differential operator.
θ_m = Mean temperature difference between steam and water across condenser tubes in degrees Fahrenheit.

(To be continued)

[10] A.S.M.E., Vol. 58, 1936, page 627.

Newcomen Society

SUMMER EXCURSION

EXCEPT that it was cut down to one day's duration instead of two, the Summer Meeting of the Newcomen Society this year was not shorn of its customary features more than every function must be under present conditions. It being impracticable to go any great distance away, a home county was chosen on Friday, the 13th inst., as the venue, and chair making was decided on as the craft to which attention should be directed.

Starting from the Institution of Mechanical Engineers, Storey's Gate, members and guests proceeded by coach to Beaconsfield, Bucks, and then by Penn to Nap Hill. *En route* in the woods that were traversed, it was observed how timber is grown specially for the industry in question. At Nap Hill a visit was paid, by the kind invitation of Mr. E. H. Goodchild, to his workshop, where he, as his forebears did before him, makes Windsor chairs entirely by hand. The product is indigenous to the county, as the name indicates, and the industry has been carried on for over two hundred years. Formerly the chairs were made of selected yew, but they are now made of beech. The method of cutting the timber, steaming the back to the requisite curve, cutting the splat (of which many traditional patterns were seen), turning or shaping the legs, and sawing out the seat (which,

by the way, is of elm), were explained by Mr. Goodchild, who then proceeded to assemble a chair. His unerring precision in cutting the mortices at the exact angles required with a spoon bit in a brace, supported in a pad against the chest, was justly admired. Time did not serve to see the finishing of the chair. The remarkable speed at which these operations are done, the consequent reasonable cost, and the individuality of the product are what enable hand work to survive for the discriminating buyer.

The party then left, *viâ* West Wycombe and Fingest, for Turville Heath, a drive of some 8 miles, where luncheon (taken with them by members on account of commissariat difficulties) was eaten *al fresco*. Mr. Samuel Rockall had been good enough to invite members to see him and his son engaged in "bodger" chair leg making, a one-man business that had been handed down for generations. The name elicited comment; probably it is the same as "butcher," and may be derived by analogy from the way the timber is cut up. Timber is felled and before it has seasoned is sawn into billets—the saw horse used attracted attention—split with a cleaver and mallet, trimmed with an axe of a pattern that must surely date from Tudor times, reduced with a draw knife on a shave-horse, and finally turned on a foot lathe, which not many years ago replaced a pole lathe. All this was engrossing.

A drive of about 6 miles brought the party to Stokenchurch to see, by invitation of Messrs. Dean and Sons, the production of chairs on the small factory scale. By division of labour and with the aid of machine tools, the timber—beech, as before—is band sawn to shape, slot mortised, turned, or rounded with cutters, and sandpaper finished. The assembling, the staining, the spray varnishing, and even the packing for carriage were likewise shown. Thus a conspectus of the art of chair making, ancient and modern, had been obtained. There was an interval for tea at the King's Arms before the drive back to town was undertaken. The countryside was in its spring green dress, the weather was propitious, and the visit was voted a success.

Sixty Years Ago

THE CHANNEL TUNNEL

AT a meeting of the shareholders of the South-Eastern Railway on June 17th, 1881, the chairman, Sir Edward Watkin, made some remarks concerning the progress being effected with the channel tunnel scheme, which seem to have frightened certain organs of the daily Press and which certainly excited our ridicule. Those who expressed fear on the subject pictured a hostile force using the tunnel as a means of invading this country. If, however, England was not to be invaded until the Channel tunnel was made, so we wrote in a leading article in our issue of June 24th, 1881, we would have immunity for many years to come. It was much to be regretted, we continued, that a man of Sir Edward's influence should have made the assertions he was reported to have made. He had stated that it would be possible to drive a driftway 7ft. in diameter from shore to shore, a distance of about 20 miles, in five years. He based that conclusion on the results of trials made by the company at Abbot's Cliff. At that point a shaft had been sunk through the old grey chalk and into the galt clay without finding a trace of water. From that shaft a gallery 7ft. in diameter had been driven a distance of 800 or 900 yards. During a recent week the progress recorded amounted to 67 yards, equivalent to 2 miles in a year. From that figure, making allowance for the fact that work would be carried on simultaneously from both ends, Sir Edward arrived at his estimate of five years to complete the gallery. If, we said, Sir Edward had consulted any competent engineer before he spoke he would have learned that the rate of progress made during a single week on shore close to the mouth of a tunnel was no evidence whatever of the average rate at which it could be advanced. As the working face advanced the difficulties of removing the spoil and of securing adequate ventilation increased very greatly and slowed down progress. We maintained that if a tunnel was ever to be made below the Channel it would have to be of practicable dimensions from the start, of dimensions sufficient to accommodate two lines of rails for the removal of the spoil and the necessarily extensive ventilating ducts. We did not assert that a tunnel could not be made under the Channel, but we maintained that no consistent scheme for making it, ventilating it and working it was at the moment before the public. There was, we said, always the danger that at any moment during the driving of the tunnel a fault in the strata might be encountered, which would result in the workings being flooded and the enterprise brought to an end. Even if successfully constructed, the tunnel, we contended, would cost so much that its successful operation could only be ensured if grants towards the cost were made by the British and French Governments. The more carefully the whole scheme at the moment before the public was considered the more was it to be regretted that any body of men should be found ready to waste money in boring holes which proved nothing and advanced the prospects of the tunnel by not one inch.

Markets, Notes and News

The prices quoted herein relate to bulk quantities. Unless otherwise specified home trade quotations are delivered f.o.t. Export quantities are f.o.b. steamer

Iron and Steel in the United States

Active conditions continue to rule in the United States and production is on a heavy scale, and is increasing as the defence programme calls for larger and larger quantities. The pig iron situation is rather irregular, and in some districts the demand exceeds the supply of foundry qualities, but distribution is carefully supervised by the producers, and consumers obtain their supplies with fair regularity. In the Birmingham district the whole eighteen blast-furnaces are in operation, but it is expected that two will close down shortly for the installation of air-drying equipment, which will increase their output by 30,000 tons per annum. Another furnace is to be rebuilt and its capacity increased by 50,000 tons per annum; another furnace in the Birmingham district which has been out of operation for a long time is likely to be restarted, and will have a production of 400 tons per day. The pig iron prices are unaltered from those ruling in the first quarter. No. 2 foundry is at 25 dollars, Bessemer 26 dollars, basic 24·50 dollars, but these prices are subject to change without notice. Some districts report a scarcity of scrap supplies. This is partly due to uncertainty over the Government price control. Dealer selection No. 1 heavy melting steel scrap is quoted 20 dollars delivered f.o.b. steel works sidings at Pittsburg and Youngstown, and 18·75 dollars in Eastern Pennsylvania. The steel production has receded somewhat to 98·6 per cent. of capacity, but the Pittsburg district is producing at 101 per cent., and Chicago at 102·5 per cent. The tin-plate mills report large export inquiries, and the industry is working at an average of 85 per cent. The Government has put into operation a system of priority ratings on steel and also essential civilian requirements. Under these regulations a buyer, unable to obtain satisfactory deliveries, may apply to the Office of Production Management, which, after investigation, may issue the necessary orders for early deliveries in cases where the material is classed as essential.

The Pig Iron Market

The consumption of pig iron in Great Britain is on an increasingly heavy scale, and although the demand for high-phosphoric pig iron still leaves something to be desired, the call for other qualities, and particularly for basic pig iron, is insistent. The consumers engaged upon war work are receiving their supplies with regularity, but the Control, which is keeping a careful eye on the distribution of pig iron, is encouraging the use of alternative irons to hematite and low phosphoric and some refined irons wherever possible. The pig iron producers in the Midlands are extremely busy as they are providing for consumers' wants in high phosphoric iron in many parts of the country, including Scotland and the North-East Coast, which were formerly supplied by local makers. The needs of the light castings makers, which are chiefly for high-phosphoric iron, are comparatively small these days, owing to the restriction on private building, and few of these firms have been fully absorbed into the war effort. The situation so far as basic pig iron is concerned is satisfactory, as the production in this country is on a high scale, and is supplemented by considerable imports, principally from the United States. There have been large imports also of hematite iron, but it is not anticipated that so much of this iron will be brought into the country in the future. A considerable demand exists for hematite iron by engineering foundries engaged on Government work, and as these requirements are of a priority character, this branch of the consuming industries is well catered for. At the same time, the Control is doing its best to persuade consumers to use substitute brands of pig iron wherever possible, and this attitude has resulted in considerable economy in the use of this class of iron.

North-East Coast and Yorkshire

Whilst those firms engaged upon war work are receiving full supplies of the finished iron and steel they require, consumers employed upon less essential work are not finding it easy to obtain material. During recent weeks the distribution of steel has been tightened up, and practically the whole production of steel on the North-East Coast is required for war purposes. Supplies of British and imported steel are adequate to meet the requirements of the war industries, and considerable stocks have been accumulated; but naturally the Control does not wish to dissipate them. There is still a restricted demand for heavy joists and fairly prompt delivery of this material is possible. In fact, some of the mills are not fully employed. On the other hand, the call for light joists and sections has been insistent for months, and shows no signs of declining. Business in sheets is active, and although the demand is not quite so strong as a few weeks ago, the makers have a good tonnage of orders in hand for both black and galvanised, a fair proportion for fairly near delivery. The shipyards on the North-East Coast are extremely busy, and are taking large tonnages of plates and partly fabricated material. The demand from this section of the consuming industries is expanding, and will probably continue to grow for some months. The munition makers are absorbing good quantities of special steels and the production of these has increased considerably. The demand for colliery steel is maintained at a high level and the output of this material passes immediately into consumption. In the Yorkshire district the basic steel plants are kept busily employed, and there is a growing demand for acid carbon steels. The call for high-class steels required in the construction of aircraft is a feature of the Sheffield trade. The pressure upon the transport services has resulted in more orders being given to the wagon builders and wheel makers, and these have been reflected in orders for steel.

The Midlands and South Wales

All the Midland steel works, both the heavy steel makers and re-rollers, are pressing production to the utmost, but efforts by consumers to obtain supplies are unrelaxed, and production passes into immediate consumption. The heavy steel works are less busy in the structural steel section, owing to the slackening in the demand for joists which has been a feature of the market for some months, although during that time the requirements of the constructional engineers and other users of heavy joists have fluctuated. Works, however, have well-filled order books, and it is difficult to place orders for most descriptions of structural steel for delivery in the current delivery period, which expires at the end of June. In some cases works have covered consumers' requirements well into the ensuing period, subject, of course, to the proper authorisation being received. The demand for deliveries is outstanding, and although easier conditions were noticeable in this department a week or two ago, the pressure has since been renewed. The demand comes principally from the shipbuilding industry, and is due to the heavy programme of work which the yards have in hand. Sheet mills also are extremely busy, both in the black and galvanised sections of the trades, and it is not easy for consumers engaged upon work which is regarded as non-essential to obtain full supplies. Special steel is being produced in considerable quantities to meet the requirements of the munition and armaments manufacturers. In the South Wales market production is at a high level, but a very large proportion of the output is required for Government work, and ordinary commercial needs have to take second place. The demand for billets, sheets, tin-plates, and bars is urgent, and is met by considerable imports from the United States to supplement the home production. On the other hand, the tin-plate market remains quiet, although at times some satisfactory orders have come on the market.

Lead and Spelter

Supplies of lead to British consumers remain satisfactory and firms engaged upon war work receive adequate and regular deliveries. There is also a certain amount of metal available for firms engaged in the manufacture of products for export. The consumption of lead for all purposes in Great Britain is on a heavy scale, and it is one of the most satisfactory features of the non-ferrous metal position that supplies are so freely available to consumers. In the United States the market is tight, largely because stocks there are low, and, in fact, do not amount to more than a few weeks' normal supply. Prices are controlled in the United States by an understanding between the producers, who are understood to be working with the Government. It is stated that some consumers in the United States have not covered their June requirements, but the attitude of the authorities there has done much to remove the likelihood of any panic buying. . . . A strong demand for spelter is in evidence, and although in Great Britain consumers engaged upon war work are well looked after by the Control, those firms engaged upon work which is not regarded as coming within the essential categories have difficulty in getting all they require. In the United States the position is somewhat similar. There is no spelter available for export in that country. The American Zinc Institute states that the domestic production in May was 64,657 short tons, against 63,305 tons in the previous month. Deliveries in May were 63,638 tons, against 63,066 tons during April. Stocks increased from the low figure of 7311 tons at the end of April to 8305 tons at the end of May. It is calculated that this is only a few days' supply at the current rate of consumption.

Copper and Tin

The situation in the copper market does not present any fresh features, and whilst supplies in Great Britain remain adequate for the war industries, the Control naturally carefully scrutinises applications for licences. In the United States the market is under a control which is apparently of a very efficient character. All buying is under supervision, so that this market is no longer subject to outside influences in the same way that it was before the institution of control. Whilst the American Government has not fixed a price, as has been done in Great Britain, it has been clearly indicated to copper producers that 12c. should be regarded as the official figure. Export quotations of about 11c. to 11¼c. f.a.s. are reported, but these are purely nominal, since there is practically no business in copper passing in the United States. The industries concerned with the American defence programme are taking large quantities of copper, but apparently supplies to works engaged on essential work are well maintained, as in this country. The question of any future shortage has been discussed, but should this arise it seems likely to result more from transport difficulties than from too small production. The lack of shipping space may affect the situation, but for the time being this trouble does not seem to have developed. . . . In the tin market a sharp reaction has occurred. There is no doubt that so long as there is no interruption of supplies from abroad the quantity of tin reaching this country is somewhat in excess of consumption. A wave of selling passed over the market last week, which may be partly accounted for by tired bulls relinquishing their holdings in view of the gradual increase in stocks. In a market in which there is little speculation and no hedging even comparatively small sales have a disproportionate effect upon prices. Since substantial sales were made both in this country and in the East, the effect was quickly visible. The American price remains above London parity. For the time being no export licences of English tin are being issued.

Notes and Memoranda

Rail and Road

U.S.A. COPPER.—The total mine production of copper in the United States (Alaska included) in 1940 was about 873,377 short tons, an increase of 20 per cent. over 1939, according to figures of the Bureau of Mines. The output in 1940 is one of the largest in the history of the United States. It has been exceeded only in the war years 1916, 1917, and 1918, and the boom years 1928 and 1929.

ANOTHER FIVE YEARS PLAN.—The Far Eastern section of the Soviet coal industry is to produce 2·7 times the tonnage of coal raised in 1937. Output from existing pits is to be expanded, new pits are to be sunk, and improved surface equipment is to be installed. These pits have not so far given good results, and transport and production facilities have been slow in developing, and important and valuable coal deposits are still without railway connections after years of planning. From 1942 about three-quarters of winning operations will be mechanised, it is hoped.

STRETCHING THE RUBBER OUTPUT.—Manufacturers of tyres in America and Canada are now using triethanolamine in mixings containing white substitute (the product made by reacting certain vegetable oils with sulphur monochloride). White substitute retards the rate of vulcanisation of many compounds, particularly those containing organic or inorganic accelerators, owing, it is believed, to the formation of hydrochloric acid during the heat treatment. The triethanolamine which is used to the extent of 3–5 per cent. of the weight of the white substitute combines with this hydrochloric acid to form a hydrochloride which apparently has little effect on the rate of cure.

SYNTHETIC RUBBER.—The Goodyear Tyre and Rubber Company, of Akron, Ohio, has its own type of synthetic rubber. A plant, with an initial capacity of 10,000 lb. per day, has been installed within the company's existing property at Akron, and plans are complete for a large expansion of manufacturing facilities, in the event of any emergency threatening the supply of crude rubber. The new synthetic has possibilities for blending with the natural product, which would serve to extend a limited supply of crude rubber. "Chemigum" tyres, which have been tested over a three-year period, are said to be superior in performance to those made of German Buna; equal, in short, to those made of natural rubber.

GRIMSHAW'S LOCOMOTIVE CATECHISM.—An educator and mentor of a bygone generation of "loco." men is dead. Dr. Robert Grimshaw, inventor and engineer in the mechanical field, has died at Englewood, N.J., at the age of ninety-one. Dr. Grimshaw was engaged for sixty years in mechanical engineering, during which time he developed a number of technical improvements in the railway industry. He was the first editor of the magazine *Power* and author of a "Locomotive Catechism," which ran through thirty editions, the last being dated 1923. This work is a 958-page handbook of questions and answers concerning practical operation and maintenance of the steam locomotive. Dr. Grimshaw was one of the founders of the American Society of Mechanical Engineers in 1880.

BEAUTIFUL BRIDGES.—A jury of award, composed of architects and engineers, has been appointed by the American Institute of Steel Construction to select the most beautiful steel bridges opened to traffic during 1940. The jury will make its selections on the basis of the photographs submitted with the entries, along with the name of the bridge, location, total cost, engineer, date completed, span length, roadway width, and so on. The American Institute of Steel Construction awards four stainless steel plaques for attachment to the bridges judged the most beautiful in the following four classes:—Class A, bridges costing 1,000,000 dollars or more to build; Class B, bridges costing from 250,000 dollars to 1,000,000 dollars; Class C, bridges costing less than 250,000 dollars; and Class D, all movable bridges.

CONCRETE TROLLEY POLES.—South African electrical interests are examining and experimenting with concrete poles, in order to reduce the consumption of steel. Those for power transmission present difficulties not yet clearly understood, but the question of trolley poles is simpler, as they are only required near towns, and the height, spacing, and loads are more or less fixed, so that a direct comparison can be made between the first cost of reinforced concrete poles and poles of other materials. An approved pole consists of three cylindrical legs braced with collars at intervals, and merging into one cylindrical top portion. With little or no change in the size of the concrete members, such a pole can be built up to any required height, and the resistance to any specified pull can be obtained by varying the reinforcing and the spacing of the three legs.

Air and Water

H.M.S. "JERSEY."—The Board of Admiralty regrets to announce that H.M.S. "Jersey" has been sunk by an enemy mine.

FROZEN WATER PIPES.—The problem of the frozen water pipe is more acute in America than here. The use of anhydrous ammonia as a thawing agent to clear them has been suggested by a New York chemical engineer. By connecting a cylinder of anhydrous material to the system and passing in ammonia, the heat generated by the solution of the gas and its rapid diffusion into the ice greatly assists thawing.

MINISTRY OF WAR TRANSPORT ADVISORY COUNCILS.—In consequence of the merging of the Ministries of Transport and Shipping, the Ministry of Shipping Advisory Council will be known as the Shipping Advisory Council and the Ministry of Transport War Transport Council as the Inland Transport War Council. The vacancy on the latter body existing since the death of Lord Stamp has been filled by the appointment of Sir Ronald Matthews, J.P., chairman of the London and North-Eastern Railway, and it has also been decided to add to this body a member with special knowledge of coastwise shipping. Mr. Robert Kelso, chairman of the General Steam Navigation Company, has been appointed accordingly.

NEW AMERICAN BATTLESHIP.—The new American 35,000-ton battleship "South Dakota" was launched at Camden, New Jersey, on June 7th. Immediately after the launch work was begun on laying the keel of the 10,000-ton cruiser "Santa Fé."

LLOYD'S REGISTER OF SHIPPING.—At a special meeting of the General Committee of Lloyd's Register of Shipping, held on June 12th, Sir George Higgins, C.B.E., was re-elected Chairman for the ensuing year, Mr. Ernest L. Jacobs, Deputy Chairman and Treasurer, and Mr. R. M. K. Turnbull, Joint Chairman of the Sub-Committees of Classification. The Right Hon. Lord Essendon was re-elected a member of the General Committee and Mr. Herbert W. Corry was elected a new member.

NEW FLYING BOATS FOR BRITISH AIRWAYS.—According to news from America, British Airways, Ltd., has taken delivery of the first of three new flying boats bought from Pan-American Airways. The first machine has been named the "Bristol" and will take up service on an Empire route; the second machine will shortly be completed and will be named the "Berwick," while the third machine, the "Bangor," is nearing completion on the Pacific Coast. The fuel tanks of the machines are enlarged in order to provide a cruising range of about 6400 miles.

LOSS OF THE G.W.R. STEAMER "ST. PATRICK."—We regret to have to record the loss by dive-bombing attack, at the end of her voyage from Rosslare to Fishguard, early on Friday morning, June 13th, of the Great Western Railway Company's cross-channel steamer "St. Patrick." About sixty-six of the total passengers and crew out of a complement of eighty-nine were rescued. The "St. Patrick" was built and engined by Alexander Stephen and Sons, Ltd., of Linthouse, Glasgow, and was completed in 1930, when she entered the service of the Fishguard and Rosslare Railways and Harbours Company. She had a gross tonnage of 1922 tons and was designed to carry 541 first-class and 372 third-class passengers. Her designed speed was 19 knots and her boilers were oil fired.

Miscellanea

ITALY NEEDS ALLOYS.—A plant for the production of vanadium alloy for the manufacture of special steels is to be built at Genoa-Ricco, for the Azienda Minerali Metallici Italiani. The Cogne Company is building a plant for the manufacture of metallic magnesium from local dolomite to be used in special alloys.

ALUMINIUM SCRAP.—The municipal authorities in Vancouver, B.C., have a new problem to solve—how to stop the theft of street lamps. In a single forty-eight hours' stretch, ten complete suspended type street lamps were stolen in the South Vancouver section of the city. It is believed the thieves are salvaging the aluminium from the light fixtures.

PULP FIGURES.—Sweden's 1940 exports of chemical pulp were less than half of the normal peacetime trade, when about 50 per cent. of the exports went to the United States and about 20 per cent. to Great Britain. Exports to the Continent have increased, but some of the output is now being utilised in Sweden for the production of cattle feed and sulphite spirit.

TWISTING WOOD.—Canadian research seems to show that the treatment of timber with urea has unexpected results. Green wood so treated is said to dry from the inside outwards, reducing the formation of surface strains and the tendency to crack. It has also been found that green wood, steeped in a urea solution and subsequently dried and heated, can be bent and twisted.

CHEMICAL ENGINEERS FOR PALESTINE.—A factory for the production of fine and pharmaceutical preparations, as well as of industrial chemicals, is projected for Palestine. The project has been backed by Mr. Simon Marks and Mr. Israel Sieff, both of London, and will be under the technical supervision of the Sieff Research Institute, of which the director is Dr. Chaim Weizmann. The works and their equipment may cost £500,000.

TALC PRODUCTION.—Among the notable features of South African mineral production for the last two years has been the expansion of the talc industry. No other mineral has boomed to quite the same extent, for last year the Union's talc output was practically quadrupled, the figures for 1939 and 1940 being 495·40 tons and 1937 metric tons respectively. Only once in ten years have four figures been previously reached, namely, 1554 tons in 1938.

A BIG MILL.—The president of the Steel Company of Canada, Ltd., presenting the annual report of the company, made mention of the additions to the Hamilton plant of the company, which include a 110in. plate mill, a tin-plate coating mill, and additions and alterations to the sheet mill. The annual rated capacity of the new plate mill is 180,000 tons. It will roll plate up to 100in. wide. Further extensions are now being carried out to increase both blast-furnace and open-hearth capacities, in order to meet the war need for pig iron and steel.

THE LIFE OF GAUGES.—In the course of a lecture on gauges, Mr. C. A. Robb, a Canadian engineer attached to the Department of Munitions and Supplies, dealt with the wear of gauges, the durability of different types of steel, and the effect of different heat treatments. The life of screw gauges was short compared with that of gauges of other types, owing to the greater length of travel of the screw gauge for each gauging operation. For example, the 2in. thread gauge when applied to the part to be measured travelled a distance of about 12ft. in gauging one part. A plain gauge of similar dimensions would travel only about 2in. in one gauging operation. Experience had shown that a hard lapped steel gauge of these dimensions could only be depended upon for about 6000 inspections before becoming worn beyond allowable limits. An overall length gauge, on the other hand, might serve for about 300,000 parts. Wear of gauges also depended upon the material and the quality of the surfaces to be measured. Thus, a gauge used in inspecting steel parts had about one-quarter the life of a similar gauge used for inspecting brass parts.

SPAIN PRODUCING MORE IRON.—Last year's production of iron and steel in Spain reached the highest levels for ten years. Pig iron output was 600,000 tons, against 457,000 tons in 1939 and 651,000 tons in 1930, the monthly figure improving steadily throughout the year. The output of steel was 751,000 tons, against 636,000 tons in 1939 and 925,000 tons in 1930. In each of ten months last year output exceeded 60,000 tons. In Viscaya, pig iron output was 428,000 tons last year, against 315,000 tons in 1939, and steel output was 485,000 tons, against 407,000 tons.

WAGES IN THE COAL INDUSTRY.—On Friday, June 6th, the National Executive Committee of the Mineworkers' Federation reached a final settlement with regard to wages in the coalmining industry, and the conditions attaching to the coalowners' offer. It has now been decided that miners throughout the country will receive an increased attendance bonus of 1s. per shift for men and 6d. for youths, which is to date back to Sunday, June 1st. Speaking after the settlement had been made, Mr. W. Lawther, the President of the Federation, said that as the Coal Production Committees will operate at each pit, whatever can be done by them will be done, in order to see that the highest requirements of the nation in the matter of coal supplies are met.

"ROPE TALKS."—We are informed by British Ropes, Ltd., that the works in which its house journal "Rope Talks" was printed has been entirely destroyed by enemy action, together with some of the company's mailing lists. If any reader who has hitherto received a copy and does not receive one of No. 16 will notify the editor, at British Ropes, Ltd., Anchor and Hope Lane, Charlton, London, S.E.7, his name will be restored to the mailing list. "Rope Talks" is one of the brightest and most interesting of the house journals which come into our office. It circulates all over the world and we can readily believe that it is very popular wherever it goes. One edition was reprinted for circulation in America by an American organisation as an example of British salesmanship.

MINERAL STATISTICS.—The U.S. Bureau of Mines reports that the estimated total values of all mineral products in the United States in 1940 were 5600 million dollars (15 per cent. above 1939), of metallic products 1650 million dollars (28 per cent. above 1939), of mineral fuels 3100 million dollars (10 per cent. above 1939), and of other non-metals 850 million dollars. The production of iron ore was the highest on record, except for 1916 and 1917. The value of the smelter output of copper and zinc from domestic ores increased 38 and 50 per cent. respectively, while the value of the output of refined lead increased 16 per cent. above 1939. Platinum, molybdenum, chromite, anthracite coal, and phosphate rock were among the few minerals which showed a decline against 1939.

Personal and Business

THE UNION-CASTLE STEAMSHIP COMPANY has announced the retirement of Mr. A. C. Grandison, publicity manager.

MR. G. R. BASHFORTH, of Round Oak Steelworks, Ltd., has been re-elected President of the Staffordshire Iron and Steel Institute.

E. H. JONES (MACHINE TOOLS), Ltd., inform us that Mr. Robert Black has been transferred to Scotland as branch manager.

THE GREAT WESTERN RAILWAY has announced the retirement of Mr. J. Auld, principal assistant to the Chief Mechanical Engineer.

MR. H. E. G. WEST, general manager of Newton, Chambers and Co., Ltd., chemical works, has been appointed managing director of the company.

WE regret to have to record the death on June 6th of Mr. David Smail, of Glasgow. He was a founder member and Past-President of the Society of Consulting Marine Engineers and Ship Surveyors.

MR. C. E. SIMMONS, vice-president and secretary, New York, Ontario and Western Railway, has been elected chairman of the board and president of the company, in succession to Mr. E. G. Buckland.

MR. GODFREY M. C. TAYLOR, M. Inst. C.E., of Messrs. John Taylor and Sons, Caxton House, Westminster, S.W.1, has been elected Chairman of the Association of Consulting Engineers for the year 1941–42.

WILD-BARFIELD ELECTRIC FURNACES, Ltd., Watford, Herts, have been appointed distributors of "Prestcold" oil coolers, recently developed by the Pressed Steel Company, of Cowley. This equipment has been included in the firm's range of heat-treatment plant in view of its application to cooling quenching oil.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of its insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

Institution of Electrical Engineers

Thursday, June 26th.—Savoy Place, Victoria Embankment, W.C.2. "Metal Rectifiers," A. L. Williams and L. E. Thompson; and "The Characteristics and Applications of the Selenium Rectifier," E. A. Richards. 6 p.m.